JUNE, 1888.

TRANSACTIONS

OF THE

AMERICAN INSTITUTE

OF

ELECTRICAL ENGINEERS.

GENERAL MEETING, MAY 16TH, 1888.

(IN PART.)

SUBJECTS:

Protection of the Human Body from Dangerous Currents.

BY PATRICK B. DELANY.

The Possibilities and Limitations of Chemical Generators of Electricity.

BY FRANCIS B. CROCKER.

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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

VOL. V. New York, June, 1888. No. 9.

SECRETARY'S BULLETIN.

At the regular monthly meeting of Council held June 5th, at No. 5 Beekman street, the following named gentlemen were elected to associate membership in the American Institute of Electrical Engineers, their applications having been properly endorsed.

F. Saxelby, Edison Lamp Co., Harrison, N. J.
W. J. Armstrong, Bishop Gutta Percha Co., New York.
David Brooks, Philadelphia, Penn.
Nikola Tesla, Metropolitan Hotel, New York.
C. J. Van Depoele, Thomson-Houston Electric Co., Boston.
Henry Van Hoevenbergh, Prospect House, New York.
Dr. Leonard Waldo, Scovill Manufacturing Co., Waterbury, Ct.
Prof. W. E. Geyer, Stevens Institute, Hoboken, N. J.
Chas. J. Goldmark, 963 Park Ave., New York.
J. Howard Pratt, Cornell University, Ithaca, N. Y.
Holbrook Cushman, 337 West 22d St., New York.
W. W. Griscom, Electro Dynamic Co., Philadelphia, Pa.

The following named associate members were transferred to full membership, upon recommendation of the Board of Examiners:

Herbert G. Smith, Quezaltenango, Guatemala.
Philip Lange, Pittsburgh, Pa.
Fremont Wilson, New York.
Frederick Reckenzaun, East Orange, N. J.
John W. Howell, Harrison, N. J.
Lewis F. Lyne, Jersey City, N. J.
John Langton, Jr., Schenectady, N. Y.
Carl Hering, Philadelphia, Pa.

As a mark of respect to the memory of the late George M. Phelps, the action of the Board of Examiners in approving his transfer to full membership was confirmed, and upon motion of

Mr. Wheeler, a committee of three was appointed by the President, to draft appropriate resolutions to be presented at a future meeting of Council.

In accordance with a resolution adopted by Council, April 3d, for the establishment of an Editing Committee, to act with the Secretary in revising the Transactions of the Institute for publication, the President appointed Messrs. George A. Hamilton, Franklin L. Pope, and Francis B. Crocker, to serve in that capacity. The following Board of Examiners was also appointed for the current year: Messrs. W. B. Vansize, Charles A. Terry, Francis W. Jones, Edward P. Thompson, and E. T. Birdsall.

The previously existing Building Committee was reappointed. The meeting of the Institute, June 19th, at which a paper was read by Mr. Frank J. Sprague, on "The Solution of the Municipal Rapid Transit Problem," being the last to be held until autumn, the latter, together with the remaining papers and discussion of the general meeting of May 16th, will be published during July, August, and September, completing the fifth volume.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

General Meeting, Wednesday, May 16th, 1888.

The General Meeting of the Institute was called to order at 10.30 A.M., on May 16th, by Mr. T. C. Martin, Vice-President.

The Chairman:—As you are aware, gentlemen, Mr. Edward Weston was elected President of the Institute last night. I have been informed that he is not at all well, and that it is possible that his sickness may, while not preventing his attendance, delay him very much in getting here this morning. I think it would be well, however, if we were to proceed immediately with our programme, and I will therefore present, as first upon the programme, the paper by Mr. P. B. Delany, on the "Protection of the Human Body from Dangerous Currents;" and as I have promised Mr. Delany to read that for him, I will ask Prof. Anthony if he will preside while I do so.

Prof. Anthony took the chair, and Mr. Martin read Mr. Delany's paper.

Read before the twenty-third meeting of the Institute, New York, May 16, 1888.

PROTECTION OF THE HUMAN BODY FROM DANGEROUS CURRENTS.

BY PATRICK B. DELANY.

Since the object of reading a paper before the Institute should be the enlightenment of members on the subject under consideration, by the presentation of facts developed by experimentation or of theories supported by a reasonable amount of investigation, I must apologize for my delinquency in both respects, and trust to the kind indulgence of the society in making a few suggestions, with a view of eliciting information and opinions from those whose experience and familiarity with the subject enables them to speak with authority.

I allude to what are considered dangerous currents and their effect on the human body. That there is danger in handling conductors conveying high tension currents must be generally admitted. The question, therefore, is, can fatal results from such currents be wholly or partially averted? All will agree that with proper care on the part of the companies and intelligent co-operation on the part of employés, but little would be heard of the danger of electric currents. But companies are economical and employés are careless. Familiarity with danger breeds contempt for it. This is exemplified almost daily in every department of industry. A new man in a powder mill will exercise the greatest care and observe all the rules of the establishment faithfully. In a few months the same man will smoke a pipe over an open powder keg.

Protection is necessary principally for those who through carelessness or ignorance fail to protect themselves. It has been

claimed that there can be no such thing as an accident—that nature has none, and that all so-called accidents are simply the results of miscalculation, bad judgment or carelessness. But it must be remembered that the vigilance of the most alert will sometimes relax, and this to them is the moment of danger.

Realizing that something should be done to protect dynamo men and wire handlers from injury from powerful currents, I, a few years since, invented a device for shunting the vital parts of the body. Partly on account of a pressure of business in other branches of electricity, but principally owing to a hesitancy in bringing out a device about the efficacy of which there seemed to be some doubt, its introduction to scientific criticism was delayed until a few weeks ago. As the references made to the question in the electrical papers have failed to elicit an expression of opinion satisfactory to any degree, it has been deemed advisable to bring the subject before this meeting.

The question to be determined is, to what extent a wire of practically no resistance, extending from one wrist to the other and bound around the wrists in numerous convolutions, so as to make good but not uncomfortable contact, will protect the vital parts of the body from fatal injury when it is placed in the path of a dangerous current through contact at the hands. It is claimed by some that the current having once entered the muscles, veins and tissue at the hands, will not leave the arms at the wrists and follow the shorter path of the wire, but will confine its course to the arms and body alone. The other opinion is that the greater portion of the current received at the hands will leave the arms at the wrists and follow the wire. The problem seems a difficult one to solve. So much depends on the condition of the person at the time of receiving a shock, a large number of tests would be necessary to arrive at results which would afford a safe basis for calculation. A few years ago Dr. Stone, connected with one of the London hospitals, made a series of interesting experiments upon patients afflicted with various ailments, with a view of determining whether or not fluctuation in their physical condition affected the electrical conductivity or resistance of their bodies. The results proved, according to my recollection, that great changes took place in the electrical resistance of the patients experimented upon from day to day, and that there was a direct influence manifested by the rise and fall of different diseases upon the electrical conductivity of the body

as a whole or in part. An account of Dr. Stone's experiments was published in *Nature* at the time. But while the experiments were most valuable for the purpose for which they were intended, they throw but little light on the subject of dangerous currents and protection from fatal injury.

Last September there was published in the *Electrical Review* of London, a paper on "Shocks from Alternating Currents," by Mr. G. L. Addenbrooke, who for some time previous had charge of the Grosvenor Gallery installation, where a primary current of 2,500 volts was constantly employed. While no one had ever come in contact with both mains at once, the writer stated that even if such an accident had happened he was "by no means prepared to assert that the result would undoubtedly be fatal." "Indeed," says he, "I rather incline to the opinion that if the subject of the shock were healthy, and the circumstances under which he received it were favorable, the chances are he would survive."

I cannot make out what Mr. Addenbrooke means by receiving 2,500 volts under favorable circumstances. It seems to me, if they are received at all, the circumstance could not be other than unfavorable. Mr. Addenbrooke himself received a severe shock, and as he speaks from experience, I quote his account of how it affected him: "The primary effect of the passage of the current through the body is, of course, to contract the muscles. The amount and persistence of this contraction depend on the quantity of the current flowing, or, as it is usually designated, *the intensity* of the shock, and varies from a simple twitching of the limbs to complete and intense contraction or rigor of apparently every muscle in the body. In this latter case, the current completely supersedes the action of the mind over everything capable of contraction or movement. Consciousness, however, is apparently rarely, if ever, lost, though the subject may be entirely unable to make any motion, cry out, or do anything to help himself. If aid is not near, such a state may be maintained for some time. On release from such a position by extraneous or natural causes, the subject is usually dazed, but if at all unconscious, soon recovers completely and experiences no further functional disturbance than the debility and nervousness naturally following such a severe strain on the system." While admitting that fatal shocks are possible, this gentleman gives it as his opinion that "if the shock is not sufficient to cause instan-

taneous collapse, apparently the body can bear the strain of the continued passage of the current for some time," and that death is caused by paralysis of the involuntary muscles controlling the heart and lungs, and that the preliminary stages of total collapse are analogous to what occurs when drowning." Referring to the local action of the current on the body where it enters and leaves, this writer also says: "If the contact is good, that is, if it consists of a good area, say of over a couple of square inches of a fairly moist skin pressed with moderate firmness against a metallic body or other good conductor, no visible injury may result. For instance, a man will often get burnt about the hands, but his feet, by which the current leaves, will be unaffected, or only slightly reddened or inflamed. Burning of the hands or other parts of the body will occur when there is imperfect contact of the body with the conductor, coming in contact with a bad or semi-conductor, such as a dirty or carbonized surface. The burning is caused by the absolute setting up of an arc."

It seems to me this gentleman's views, based, as we are led to believe, on actual experience, are somewhat paradoxical. And surely numerous cases of deaths from currents recently, disprove many of Mr. Addenbrooke's deductions. True, nothing short of death is made public, so that there is but little information to go upon relating to the instances which must be of frequent occurrence where men are *almost* killed by electric shocks. In all cases that have come to light, whether simply injuries or cases of death, the parts of the body coming in contact with the current have been badly burned. The unfortunate "trouble hunter," who lost his life a few days since, was not only burned at the hands but at the knees. In cases where the shock is not instantly fatal, may it not be that the burning of the flesh at the points of contact is so great as to destroy to a considerable extent the conducting substance in contact with the wire, and thereby cause a fall in the current passing through the body? It is certainly owing to the fact of the body being a very poor conductor that harm is done. If it offered no resistance there would be no realization that a current was passing through it. An arc would be created at the point of contact, provided the contact was *imperfect*, but the body itself would be uninjured. It seems to me that the human body must be viewed as any other semi-conductor, with the exception perhaps of susceptibility to greater change under the continued action of a current owing to the fluids which

it contains. It is owing to its resistance that a carbon filament becomes incandescent.

The carbon rod of an electric lamp is not consumed except at the point where the arc is formed by the resistance of attenuated particles under combustion. Any conducting substances placed in the path of more current than it is capable of conveying must be heated, consumed or decomposed, according to their nature and in proportion to the discrepancy between the conducting capacity of the conductor and the sum of the current.

Now if we liken the human body from hand to hand to a canvas hose or tube filled with water and which allows a certain quantity of moisture to ooze through the surface, corresponding to the moisture of the skin, and if this be inserted in a circuit, connection being made at the extreme ends, corresponding to the hands, and a shunt wire of minimum resistance be wound around the tube two or three inches from the ends, corresponding say to the wrists, we can, perhaps, more understandingly speculate on the action of a dangerous current on the human body, contact being made at the hands and the shunt wire encircling the wrists. It should be borne in mind that the contact between the shunt wire and wrists is much better than the contact at the hands, since the wrists are more tender than the hands. Now, referring to the tube, and assuming that the contacts at the ends have improved by reason of the currents eating its way into the water, does it not follow that the current instead of following the entire length of the tube of water, offering, say thirty times the resistance of the two or three inches of water from the end of the tube to the shunt wire, and several thousand times the resistance of the shunt wire itself, will, to a great extent, pass from the tube to the shunt wire and in its passage *improve* the contact at that point as it did at the ends in entering the tube? I have often noticed that upon receiving a shock of 150 to 250 volts profuse perspiration instantly followed. This would greatly improve the contact at the wrists above the normal, so that it would seem impossible that the current should confine itself to the fluids and muscles of the body in preference to the wire when separated from the wire only by thin, tender skin filled with moisture.

In considering the danger point of currents it seems reasonable to recognize the same law, or rather recognize the absence of any law, governing other destructive agencies. Let it be concussion, strain, asphyxia, poison, or other enemy of endurance, there are

hardly two cases alike. One man may emerge with but slight injury from a cause which to another man would be death. Why should it not be so in the matter of electric shock? Death, of course, must be the consequence of a certain degree of cause. If 2,000 volts are necessary to kill in any instance, one volt less would avert death, while shunting 100 or 500 volts would leave a proportionate margin of safety. Fatal results through the medium of electricity do not come by jumps any more than by any other force or element of destruction. There is in this subtle agency, as in all others, a last straw which breaks the camel's back—a last volt which does the final harm. Hence the importance of protecting, as far as possible, those exposed to this danger.

Regarding the immediate cause of death or the effect of currents on the substances of the body, we must look to the medical men for light. Probably all subjected to shock might not be similarly affected. In one case it might be the heart, in another, the brain, and in others, the lungs that might be injured. Why not have a thorough investigation of this subject, and then perhaps wire handlers may be subjected to an examination before they are allowed to engage in such work, just as men are examined for various other duties.

There seems to be so little known about these matters, I shall feel gratified if this paper serves as even a feeble incitement to discussion and investigation, as I can conceive of no subject offering a more humane incentive.

DISCUSSION.

Mr. G. M. PHELPS, Jr.:—I suppose it will be somewhat difficult to bring the merit of the proposed protection to a test by a trial by linemen, or upon any person. There will probably be few investigators enthusiastic enough to learn the possibilities of this protection by submitting to a test. But unless electricians share the sensibilities of the Anti-vivisection Society, a great deal might be learned as to the efficacy of the means of protection suggested by Mr. Delany by judicious experiments upon animals. I suppose there will be an opportunity to get an abundant supply of dogs of various sorts the latter part of the summer. I merely make that suggestion as pointing out a method of testing the efficacy of this means of protection. I am quite serious about it. I can see no reason why very satisfactory tests might not be ap-

plied to various animals, and some of these physiological questions implied in Mr. Delany's paper be determined to a great extent.

MR. MARTIN:—Mr. Delany was not at all anxious that the apparatus he had devised should be exhibited, not desiring in any way to use the Institute as an advertising medium. I was very much interested in the subject myself, however, and I took the liberty of bringing some of the apparatus with me. If it be the desire of the members, I will show it.

(MR. MARTIN exhibited the apparatus.)

MR. R. W. POPE:—Mr. President, one of the difficulties encountered in the practical application of a safeguard of this kind, according to my investigations, has been the difficulty in enforcing its use among the very men whom it may be intended to protect. I have heard it stated that miners were averse to carrying safety lamps, and we all know that there are insulated pliers now on the market, and that India rubber gloves when perfect, answer as a protection; yet men go out on their daily duties without taking even these precautions, and consequently we need something more than the actual invention of a device that will perform its duty in order to save lives. If men are so careless and so regardless of the danger as to go out on their duties without preparing against it, I do not see how we can do anything to wholly prevent accidents.

MR. JOSEPH WETZLER:—In looking at the question from another standpoint, it strikes me that the question which is involved in the fatality of an electric shock, depends to as great extent on the electric work done upon the body, as upon the potential. Let us take, for instance, the case of a man struck by lightning. We frequently hear of men having been struck and surviving. Here there can be no question of the fact that the potential was at least many hundreds of thousands volts. Yet on the other hand we see a man touching a wire of 1,500 or 2,000 volts and being killed. In one case we have an enormous potential, but an exceedingly small current; in the other case a comparatively small potential, but a large current; yet in the latter case the electric work far exceeds that of the lightning stroke and the man's death ensues. Therefore I should say that the question involved as much the electric work done upon the human body as the potential; and if by means of such an apparatus the work done in the human body can be decreased, I think it would have in that sense some value; that is, if you could

shunt a large part of C, a man's life might be saved, whereas if it were not shunted it might enter his body and cause his death.

PROF. P. H. VANDER WEYDE:—We have lately seen in the electrical journals assertions about the number of volts of potential of current people can stand without injury. It has been stated that a thousand volts could be taken with perfect impunity. But those writers forget that there are two elements to be considered—the potential and the quantity, as stated by the last speaker. It is the product of amperes and volts which does the damage. When we have a great potential, as in a friction electrical machine; we may have, as Prof. Mayer, in Hoboken, lately showed, many thousands of volts potential but no quantity. It will penetrate a distance easily, but the quantity transmitted is very small, so that it is harmless. The sparks of a friction machine do not cause serious damage. But when we take the other extreme, larger quantity and greater number of amperes, it is different. We find that in the thermo-electric pile there is not sufficient electromotive force to penetrate the skin. It has no effect on the body. There is not enough electromotive force even to pass through the liquids of the body. In the galvanic battery, we have electromotive force if we use a sufficient number of elements and we have quantity if our cells are large enough. There we may have a shock, and a battery of that kind—as large as Sir Humphrey Davy used, of some four thousand elements—may be fatal to an experimenter. It is the relation between the two. There must be a sufficient number of volts and a sufficient number of amperes together, in order to destroy life. That is the case with lightning. Usually lightning is fatal, because there is sufficient quantity, and at the same time there is electromotive force, as we see by the enormous length of a stroke of lightning. So it is with dynamos; when high electromotive force is combined with sufficient quantity, it becomes dangerous; but I want to impress upon all, that electromotive force alone, without quantity, is harmless, and so, also, great quantity alone is harmless. It is the combination of the two in which lies the danger.

PROF. ELIHU THOMSON:—Mr. President, I quite agree with Dr. Vander Weyde in the opinion expressed that it is not a question of volts or current alone which determines the fatality of a shock. It is quite possible, no doubt, to take a charge through the human body equal to many thousands of volts. One may mount an in-

sulated stool and be charged to a potential of ten or fifteen inches of striking distance, and have it discharged from him with no more discomfort than would result by the discharge through his body of a very small Leyden jar. That I have had experience in myself, and I can testify that even though such a charge as that goes directly across the body of a person it has no harmful effects, other than a very slight shock, causing a twitching of the arm. In all cases of dangerous shock it seems to me that we must have a resistance so low as to permit the volts to send a current of a certain volume through the system. If that current is not attained, it is doubtful whether harmful results will follow. If that current is attained, the harmful results may follow. If we could imagine a man constituted so as to have not more than an ohm resistance separating any two portions of his body between which are situated vital nerves — nerves whose action is required to keep up the functions of the respiratory organs or the heart—it is quite conceivable that a very small voltage might kill the man. Human subjects undoubtedly differ very greatly in resistance, and a fatal shock may be obtained in one case at one time, which would not be obtained by the same subject at another time with equal voltage, much depending on the moisture of the skin, and probably the amount of salty matter in the blood. The layer of fat which exists underneath the skin acts as a sort of insulator. All these things will have an influence, and then comes in addition the susceptibility to a discharge. We have reason to believe, I think, that susceptibility varies very greatly in people. I quite agree also with Mr. Phelps in the necessity of some really scientific investigations tending to clear up this question. Those investigations, I think, could be carried on with the lower animals, and very valuable data arrived at, as to the passage of the current in certain directions through the body; whether the current in its passing includes, say, the pneumo-gastric nerve, which, if it does not act, is sure death every time. The heart must beat in order that life be sustained, and death will occur from heart failure if the heart is not kept beating. If, in like manner, the nerves controlling the respiratory functions have their vitality exhausted, that will also be a cause of death. The whole organism depends, I think, upon the nervous system, and hence it is a possibility that such a thing as nervous polarization may occur. The molecules constituting the nerve fibres may become set or polarized, so that

the brain's excitation cannot reverse them nor bring them back to a normal condition. This idea has been suggested as a means of resuscitation—a discharge passed in an opposite direction would, as it were, depolarize the nerves and assist recovery, followed by artificial respiration and other means at command. It has been stated, I think by D'Arsonval, that in his opinion the alternating current is not as apt to produce fatal results as the direct current, and particularly direct currents in the nature of sudden discharges or shocks similar to lightning discharges, in which a large volume of current is sent through in intermittent impulses or in one impulse of considerable power. He, I believe, holds to the opinion that in cases of injury by alternating currents resuscitation may occur, in many cases, by artificial respiration. If this is true, it would seem that polarization has something to do with it, which is prevented in the case of alternating currents, because they are continually reversed. The fact also is certainly true that cases of very severe injury are known, where men have been subjected to a very high potential current and all the evidences of the passage of a heavy current through their bodies have been found, and the men have not suffered any great inconvenience other than the burning of the hands, so that it would seem as though a critical condition existed in some cases which was not present in others. Whether the person himself has any extra power of resistance, or whether his nervous system is so toned up as to be capable of recovering after he has been partially injured is a question which would naturally arise in connection with this case. I cannot agree that it is a question of one volt more or less whether a man is killed or not. I think the time element is probably the most important of all. There are cases in which men have been struck by lightning, and, as you all know, have recovered. Discharges of potential of millions of volts have passed through their bodies and they have recovered, and in such cases the discharge was undoubtedly a sudden one, and the current passing must have been very considerable. I cannot regard a lightning flash as an example of a small current. The heating effects which are present in such cases are sufficient to show that the current may rise to very many hundreds of amperes. For example, if a lightning flash will deflagrate a small iron wire in a very small fraction of a second, it means that current, not volts, has done the work, and not only that, but a very large current. It may have existed for but a

short time, but it certainly did exist, and the very suddenness of the action is in favor of very high current flowing. We have numerous instances of telegraph and telephone wires and other small conductors melted by the electric discharge from the clouds, and when we consider the conditions, we must see that the current is large. We have only to look at a lightning discharge to see that it may appear to us as thick, sometimes, as a telegraph pole. That, if it means anything, means a body of vapor highly heated, of some considerable area. But lightning discharges, according to my observation, are not always single and alone. They are sometimes repeated half a dozen times down the same path, and it is not to be wondered at that a man receiving, say, a discharge of half a dozen flashes down the same path in rapid succession, might be killed, whereas a man receiving one flash, might escape. I have noted that fact by simply keeping my head going during a thunder storm and keeping my eyes fixed in one direction, so as to catch the flashes, and they arrange themselves in parallel lines, oftentimes. I have counted as many as six in that way, very quickly following each other.

DR. VANDER WEYDE:—I had an opportunity some twenty years ago of making experiments regarding the susceptibility of different persons to heavy shocks, when I was professor at the Cooper Institute. We had a Rhumkorff coil which gave sparks of twelve inches, and which, by some improvements in taking away all possible edges on the binding posts, I increased to 16 inches. In making the experiment I was a few times knocked down—not actually knocked down, so much as that I had to sit down; I could not help myself. I spoke of it to Mr. Kidder, well-known as a practicioner using slight electric shocks for medical purposes. He came to my place frequently, and I gave him advice about his machine. He said that the idea was exaggerated that such a Rhumkorff coil was so dangerous, and he was willing to take the strongest shock I could give. I said to him, "If you want to take a risk, I am ready, but bring witnesses." He came with witnesses, one of them being a reporter of the *New York Tribune*. I gave Mr. Kidder small shocks at first, gradually making them larger and larger, and he stood them perfectly and they did not knock him down. He had great power af resistance in that respect. The next day a sensational article was published in the *Tribune*, headed, "An Error in Science Exploded," and there it was said that all the talk that electricity could kill was

nonsense; that the strongest machine which ever had been made was now at the Cooper Institute—that it was the strongest was proved by the fact that it cost not less than $400, and that Mr. Kidder, the well-known electrician, had stood all the shocks from it, and it gave a great many details which are very amusing to a man posted in electrical science, written by a reporter who was not familiar with the subject. It is strange to me that some persons have such great resistance.

Dr. Otto A. Moses:—The proposed experiments on animals would be very interesting, but it would be very difficult to make the conditions sufficient to satisfy all the requirements that are necessary for accurate experimentation. If you consider that the resistance of a man's body may vary under certain circumstances from ten or fifteen thousand ohms down to four or five ohms, it will be seen that it is necessary that the experiment should be methodically conducted. The skin is an excellent insulator, the blood an excellent conductor, the perspiration an excellent conductor. The varying pressure that we apply in coming in contact with a conductor is a cause of immense variation in the amount of current that passes through us. In fact, we may assume that our nerves convey impressions to us simply by the varying pressure that we give to an object, in that way bringing more or less vital electric action, or whatever it may be, into play. An interesting experiment will prove how variable the quantity of current, passed through a conductor, may be. At the time Mr. Edison was experimenting on a carbon telephone, he thought it essential, and it is essential that a uniform pressure should be upon the carbon buttons of the transmitters. All of his experiments were made under uniform conditions. For instance, in the ordinary carbon button, which was about one or 1½ centimeters in diameter, he applied usually a weight of one gramme, and he found then that they had a resistance of about one ohm, but varying hydrometric conditions affected the conductivity. A passing thunder-storm, causing the absorption of moisture by the carbon, produced a variation in the quantity of current passing through. So, without any apparent changes, we have evidently got changes of resistance. The skin varies in thickness, so that it is necessary in making experiments, to take one constant place and one constant thickness. It will be a very difficult thing to try the experiment, but still it would lead to good results.

With regard to the point that Prof. Thomson raised, that it was

possible for a man to live after having received a severe stroke of lightning. That is quite true. But I think it may be ascribed to the fact, that in such a case the man's clothes would naturally be saturated by the rain and thus become excellent conductors. The man is struck, but the wet clothes serve to carry the current more than the body. There is probably an induced action that affects the man, but the skin, being an excellent non-conductor, furnishes such insulation that most all the current passes through the wet clothes.

With regard to the quantity of current that will affect the sensations, one or two interesting experiments may be not unacceptable. If you make a single battery of zinc and copper placed above and below the tongue, you will feel a slight shock, you will taste a slight acidity, and you will also see a flash which, with sensitive persons, becomes unpleasant. There you have an electromotive force of about a volt and a very small quantity of current. If you take through the temples 100 volts from a like number of ordinary Daniell's cells, you will get a very unpleasant stunning effect, but not a painful one. There you have the brain brought right in between the terminals; whereas if you were to take a shock from a Rhumkorff coil, such as Dr. Vander Weyde spoke of, where the spark was 16, 17, or 20 inches, you would be able to actually transfix yourself if you were of sufficiently high resistance. We have all seen blocks of glass, four or five inches in diameter, pierced by a spark from a Rhumkorff coil. So there, if the body is thoroughly insulated by the dry skin, and the spark not able to pass by mean of the skin, it might pass through the brain in that case and cause instant death. It would be very difficult to trace the passage of the spark, but I think death would be caused in that way. The location of the terminals, too, has very great influence on the sensitiveness. I myself am exceedingly sensitive to the smallest shock. It is so unpleasant that what could be borne by almost anybody puts me in a profuse perspiration. So that it varies immensely in individuals.

(Mr. Martin here assumed the chair.)

Mr. Francis B. Crocker read the following paper on "The Possibilities and Limitations of Chemical Generators of Electricity."

THE POSSIBILITIES AND LIMITATIONS OF CHEMICAL GENERATORS OF ELECTRICITY.

BY FRANCIS B. CROCKER.

Electro-chemistry seems less generally and less clearly understood than any other branch of electricity of equal importance. The facts concerning the dynamo, motor, telegraph and telephone are widely and definitely known; but there are ideas, statements and claims in regard to batteries which are further from the truth, more prevalent and go longer without being contradicted than any other collection of errors that I can call to mind.

Primary batteries have not received the attention in this country that they have abroad, particularly in England, where the successful or unsuccessful attempt to float a new primary battery company is a matter of almost weekly occurrence. Nevertheless the subject is a sufficiently important one, and the false ideas of which I have spoken have spread so far beyond the quacks, to whom such ideas are usually confined, that the subject deserves more study than it usually receives, particularly from the scientific standpoint.

Electromotive Force.—The electromotive force which a given battery or combination of materials will develop is the first and most important question in electro-chemistry. Of course the best and surest way to arrive at this E. M. F. is to determine it by actual experiment with a voltmeter, or, still better, by comparison with a standard cell. There are, however, many times when the materials or instruments are not at hand, and a calculation or predetermination of the E. M. F. is very convenient.

The formula for calculating the E. M. F. is obtained by assuming that the electrical energy of the given chemical combination is equal to the heat energy which the same combination is capable of producing, or $E\,C = 4.16\,C\,a\,H$, that is, volts multiplied by coulombs is equal to the coulombs multiplied by the electro-

chemical equivalent, *i.e.*, the weight of material required per coulomb and that by the heat produced by one gramme of the material. The electrical equivalent of heat 4.16 is introduced to reduce both members of the equation to an electrical basis. Cancelling the C in both members, we have $E = 4.16\ a\ H$, in which E is the E. M. F. in volts, a is the electro-chemical equivalent (grammes per coulomb), and H is the number of heat units (gramme-degrees Cent.) produced per gramme of material by the given chemical combination. The values of a and H are given for most materials in electrical and chemical books of reference, and the calculation is a very simple one, nevertheless this formula and the principle involved in it are not generally understood and are very seldom used. The equation deduced above is that ordinarily given, but what I have found to be a more convenient form of it is obtained by assuming that $E = 1$, giving a its value for hydrogen (.00001035). Solving with respect to H we have $H = 23300$, which means that 23300 is the number of heat units per equivalent corresponding to one volt, and all that is necessary to find the volts of any given chemical combination is to divide the number of heat units per equivalent (which is the form they are almost always given in) by 23300 and the quotient is the E. M. F. in volts. For example, to obtain the E. M. F. which zinc and free chlorine will develop divide 48,600 (which is the number of heat units produced by the combination of one equivalent of zinc with one of chlorine as given by Thomsen) by 23,300, and the result 2.09 is certainly very close to 2.11, the actual value obtained by experiment. In the same way the E. M. F. of other combinations of materials may be predetermined, but it should be always borne in mind that the heat of combination corresponding to one *equivalent* of the material should be taken and not necessarily that corresponding to one atom; as for example in the case of zinc, the heat per atom (65 grammes) is 97,200 which has to be divided by 2 to reduce it to one equivalent because zinc is a dyad and takes two atoms of chlorine, which is a monad. In the case of monad metals like sodium, potassium and silver the figures may be taken just as they are given in the tables. Mistakes very frequently arise is this way; in fact I do not think I ever saw a table of electro-chemical equivalents in which this point was correctly introduced in every case.

In order to test the practicability and accuracy of calculating E. M. F., as well as to obtain reliable results and full data for

their own value, I determined the E. M. F. given by thirteen of the most important metals in combination with free chlorine, bromine and iodine, and the results are given in tables A, B and C respectively. In table D, I have averaged the results and placed them side by side with the results obtained by calculation. The agreement between the two sets of figures is not perfect by any means, but when it is remembered how the E. M. F. of a cell will change one or two-tenths of a volt on apparently the slightest provocation, I think the figures are strikingly close, more so than I expected to find them. In more than half of the cases the difference is less than one-tenth of a volt, and the average difference is only slightly more than that. There has been no warping or coaxing of the figures to secure uniformity. The results are given just as they came. If figures were picked out from the different observations, it would be possible to obtain almost perfect agreement between the calculated and the determined, as one may see by looking over the tables.

In regard to the experimental results as given in tables A, B and C, I may state that all the metals and salts used were chemically pure, with the exceptions of the metals magnesium and aluminium, and these were of a very good quality. Pure carbon plates were used for the negative plate, but platinum was also tried and gave substantially the same results. The E. M. F. was measured by a Thompson reflecting galvanometer (by Elliott) using two independent standard Daniell cells. One fact which strikes one in looking over the tables A, B and C, is that the E. M. F. is not very greatly affected by the solution; a certain metal gives about the same result in one chloride as in another, and the same is true of the bromides and iodides. In table E, I have given the E. M. F. obtained by substituting different metals for the zinc in a Daniel's cell, but these results being from only one series of observations are probably not so reliable as those in the preceding tables.

In the remaining table I have collected in condensed form the principal facts in regard to batteries in which zinc is used as the electro-positive material with the most important electro-negative or depolarizing materials. The facts in regard to metallic zinc, which hold good in all cases in which it is used (no matter what the other material is), are given on a horizontal line with zinc. Below this the facts in regard to each particular combination are

given opposite the depolarizer. For example, the data of a zinc and chlorine battery are given on a horizontal line with chlorine, of a zinc and nitric acid (Bunsen) battery on a line with nitric acid.

TABLE A.

E. M. F. produced by different Metals in Combinations with Free Chlorine in Solutions of —.

	Magnesium Chloride.	Zinc Chloride.	Zinc Chloride.	Zinc Chloride.	Hydro-Chloric Acid.	Common Salt.	Average.
Magnesium	2.83 2.65	2.65			3.2–3.15	2.85	3.1
Zinc	2	2.20	2.13	2.11	2.20	2.18	2.11
Cadmium		1.94		1.86	1.98	1.93	1.9
Aluminium	1.75	2.04	1.88		2.02	1.98	2.
Iron		1.60	1.56	1.5	1.67	1.68	1.6
Cobalt		1.43	1.43	1.41	1.50	1.45	1.43
Nickel		1.33		1.27	1.40	1.33	1.33
Tin	1.50	1.70	1.6	1.57	1.68	1.66	1.61
Lead		1.63	1.62	1.60	1.68	1.65	1.63
Copper		1.31	1.30	1.29	1.37	1.34	1.32
Silver		1.11	1.12	1.13	1.15	1.10	1.11
Antimony		1.20	1.23	1.25	1.25	1.08	1.22
Bismuth		1.29	1.25	1.20	1.27	1.19	1.21

TABLE B.

E. M. F. of different Metals with Free Bromine in solutions of

	Magnes. Bromide.	Nickel Bromide.	Potass. Bromide.	Hydro-Bromic Acid.	Magnes. Br'mide weak.	Average
Magnesium	2.55	2.45	2.51	2.7	2.57	2.56
Zinc	1.84	1.78	1.82	1.79	1.85	1.79
Cadmium	1.6	1.54	1.62	1.57	1.61	1.58
Aluminium	1.5	1.46	1.47	1.46	1.6	1.53
Iron	1.29	1.25	1.31	1.26	1.33	1.3
Cobalt	1.1	1.09	1.05	1.06	1.13	1.05
Nickel	.8	.85–.8	.8	.87	.94	.85
Tin	1.12	1.31	1.3	1.25	1.27	1.3
Lead	1.4	1.27	1.33	1.28		1.33
Copper	1.05	.96	1.01	.99	1.03	1.02
Silver	.97	.94	.97	.95	.93	.95
Antimony	.99	.78	.71	.87	.97	.8
Bismuth	.92	.9	.96	.88	.92	.92

TABLE C.

E. M. F. of different Metals with free Iodine in solutions of —,

	Magnes. Iodide.	Zinc Iodide.	Potass. Iodide.	Average
Magnesium	2.02		2.00	2.01
Zinc	1.35	1.23	1.29	1.25
Cadmium	1.12	1.12	1.13	1.12
Aluminium	.92	.83	.87	.88
Iron	.69	.6	.74	.68
Cobalt	.6	.42	.5	.51
Nickel		.35	.37	.36
Tin		.72	.69	.71
Lead		.82	.85	.83
Copper	.63	.67	.62	.64
Silver	.65	.67	.64	.65
Antimony	.41	.47	.46	.44
Bismuth	.39	.46	.42	.43

TABLE D.

Comparison of the E. M. F. Calculated from the Heat of Combination and the E. M. F. determined by experiment.

Metals.	Combining with Chlorine Calc.	Determ.	Bromine Calc.	Determ.	Iodine Calc.	Determ.
Magnesium	3.24	3.1				
Zinc	2.09	2.11	1.68	1.79	1.05	1.25
Cadmium	2.	1.9	1.58	1.58	.97	1 12
Aluminium	2.3	2.	1.7	1.53	1.00	.88
Iron	1.75	1.6	1.5	1.3	.85	.68
Cobalt	1.64	1.43				
Nickel	1.57	1.33				
Tin	1.71	1.61	1.5	1 3		
Lead	1.76	1.63	1.38	1 33	.85	.83
Copper	1.4	1.32	1.07	1.02	.69	.64
Silver	1.25	1.11	.97	.95	.59	.65
Antimony	1.3	1.22				
Bismuth	1.3	1.21				

TABLE E.

E. M. F. produced by different Metals substituted for the Zinc in a Daniels cell.

Metals.	Volts.	Metals.	Volts.
Zinc	1.08	Lead	.58
Cadmium	.79	Copper	.07
Aluminium	.65	Silver	—.02
Iron	.64	Antimony	.09
Cobalt	.40	Bismuth	.17
Nickel	.1		

SYMBOLS. — Chemical expressions reduced to a common basis.	CHEMICAL EQUIVALENTS. — Proportions in which materials combine. H=1.	ELECTRO-CHEMICAL EQUIVALENT. — Weight of material consumed per amp. sec. milligrams per coulomb.	NAME OF MATERIALS.	Electro-motive Force produced. Volts.	Weight of zinc consumed per Horse Power hour. Pounds.	Weight of Depolarizer consumed per Horse Power hour. Pounds.	Weight of Materials consumed per amp hour in each cell. Pounds.	Cost of Materials wholesale. Per Pound.	Total Cost of both positive and negative materials per Horse Power hour.
½ Zn	32.5	.337	Metallic Zinc,				.0027	$.07	
+			used with following electronegative or depolarizing elements:						
I	127.	1.314	Free Iodine	1.2	1.67	6.53	.0105	3.50	$22.97
Br	80.	.828	Free Bromine	1.79	1.12	2.76	.0066	.38	1.12
Cl	35.5	.367	Free Chlorine	2.11	.95	1.04	.0029		
½ O	8.	.083	Free Oxygen*	1.9	1.05	.26	.00066		
½ S	16.	.166	Free Sulphur*	.95	2.1	1.03	.0013	.02	.17
			CHEMICAL COMPOUNDS.						
½ H_2O	9.	.093	Water *	.5	4.	1.1	.00074		
HNO_3	63.	.652	Nitric Acid	1.9	1.05	2.04	.0052	.06	.20
½ CrO_3	33.4	.346	Chromic Acid	2.	1.	1.03	.0027	.20	.28
½ $CuSO_4$	79.7	.826	Copper Sulphate (anhyd.)	1.079	1.86	4.55	.0065		
½ $CuSO_4 \cdot 5H_2O$	124.7	1.29	Copper Sulphate Crystals	1.079	1.86	7.13	.0102	.06	.56
½ Fe_2Cl_6	162.5	1.683	Iron Perchloride	1.55	1.3	6.5	.0133	.10	.74
AgCl	143.5	1.487	Silver Chloride	1.06	1.89	8 32	.0118	16.00	133.25
½ $HgSO_4$	248.	2.57	Mercury Sulphate	1.42	1.41	10.7	.0204	.50	5.45
			MIXTURES.					Mixture per lb.	
½ { $K_2Cr_2O_7$ / $7H_2SO_4$ }	163.5	1.694	{ Potass. bichrom, 3 pts. / Sulphuric acid, 7 parts }	2.	1.	5.03	.0133	.04	.27
½ { $K_2Cr_2O_7$ / $4H_2SO_4$ }	229.	2.37	{ Potass. bichrom., 3 pts / Sulphuric acid, 4 parts }	2.	1.	7.04	.0186	.05	.42

* Calculated.

For convenience the table is divided into two parts; the left-hand side contains the purely scientific data, and the right-hand portion contains the practical facts.

In the first column of the first part is given the chemical symbols reduced to a common basis, any one of the expressions being chemically equivalent to any other. For example, one-half atom of zinc ($\frac{1}{2}$ Zn) requires one atom of chlorine (Cl), or one-half atom of oxygen ($\frac{1}{2}$ O), or one-third molecule of chromic acid ($\frac{1}{3}$ Cr_2O_3), or one-sixth of the mixture of one molecule or potassium bichromate and seven molecules of sulphuric acid ($\frac{1}{6}$ [$K_2Cr_2O_7+7H_2SO_4$]), and so on.

In the second column I give the chemical equivalents which are simply the proportions by weight required of the different materials. That is, when we use 32.5 grammes of zinc (hydrogen being assumed as one gramme), we require 35.5 grammes of chlorine, or 33.4 grammes of chromic acid, and so on.

The third column contains the electro-chemical equivalents, which are really exactly the same and directly proportional to the combining weights in the previous column, but are reduced to an electric basis of so many milligrames per coulomb. To convert these figures into grammes per ampère hour simply multiply by 3.6.

In the first column of the second part of the table is given the E. M. F. of each combination, all of which with the exception of oxygen, sulphur and water are determined by experiment, most of them being well known and accepted values. In the case of oxygen, sulphur and water the E. M. F. is calculated as explained above and is merely given for comparison. No actual battery corresponding to these materials exists.

In the second column on the right-hand side, is given the number of pounds of zinc required per horse-power hour in the case of each combination. For example, a zinc and copper sulphate (Daniell) battery, requires 1.86 pounds of zinc per horse-power hour of electrical energy produced.

In the next column I give the weight of depolarizer required per horse-power hour in the case of each combination. For example, a battery requires 5.05 pounds of the mixture of three parts of potassium bichromate, and seven parts of sulphuric acid, which is about the ordinary strong bichromate solution for porous cell batteries. Of course the water required for the solution is not considered here or in any of the other figures of the tables,

because it cost nothing and serves merely as a medium of electrical action; but if the total weight of solution is desired, the weight of water must be added.

The weight of the different materials consumed per ampère hour is given in the next column. These figures are obtained directly from the electro-chemical equivalents in the third column by dividing by 125; in fact, they are simply the electro-chemical equivalents in pounds per ampère hour.

It should always be carefully noted that the weight consumed per ampère hour is that required in *each cell* in *series*, whereas in the case of horse-power hours the weight given in the table is the total weight used, no matter how many cells there are or how they are arranged.

In the next to the last column is given the wholesale cost per pound of the different materials. These prices are of course very difficult to fix, because they depend upon the market and vary greatly upon the quantities bought; but the prices I have here are very low and ordinary consumers would have to pay twice as much in most cases; they give, however, some idea of costs.

In the last column I have given the cost of both materials, zinc and depolarizer, added together. I have not here considered the values of the products, because it is very difficult to estimate the cost of collecting and utilizing residues. In the case of silver chloride the silver resulting from the action would, of course, be worth a large portion of the cost of the original chloride.

One of the interesting points which this table shows is the total weight required by horse-power hour. For example, .95 pound of zinc and 1.04 pounds of chlorine, making a total of almost exactly 2 pounds, would produce one horse-power of current for one hour, if all of the chemical energy could be converted into electric energy.

This brings up the question of how large a percentage of the chemical energy can be utilized, or, in other words, the efficiency of chemical generators. This efficiency is higher, I think, than it is generally supposed to be. I have no exact figures upon this point, but I have tested several times the weight of zinc consumed compared with the theoretical amount, and I have found that even in a plunge battery, where the bichromate solution was directly in contact with the zinc and the opportunity for local action was a maximum, that the zinc efficiency was as high as 75 per cent., and in one case 80 per cent. In a porous cell bat-

tery with amalgamated zinc, where there was little or no cause for local action, I believe the zinc efficiency would be as high as 90 per cent., and I should not be surprised to find it as high as 96 or 97 per cent.

The efficiency of the depolarizer is generally lower than that of the zinc, because there is generally a good deal of chemical energy left in the solution after it is too weak for satisfactory work. The efficiency of the bichromate solution in the plunge battery I have just referred to was only about 45 per cent. of the total theoretical power. But this is very low, because the solution has to be weak in acid in account of being used in contact with the zinc. In the case of a copper sulphate battery, where the crystals of sulphate are often almost entirely used up, I think the efficiency would be as high as 80 or 90 per cent. The efficiency I speak of here is simply the *chemical* efficiency in the battery; the fall of potential in the battery due to its internal resistance compared to the external is another loss which has to be added to the chemical loss in determining the total efficiency.

The possibilities of chemical generators are therefore almost infinite, since it requires theoretically a total of only 2 pounds of zinc and chlorine, and 2 pound of zinc and chromic acid per horse-power hour, and since the efficiency of batteries can easily be made as high as 75 per cent. it follows that less than three pounds of material is actually required per horse-power hour; but unfortunately the water for the solution, the containing vessel, electrodes, etc., are so heavy that the total weight is very many times greater. The possible and the actual battery are thus very far apart. If we use metals of higher chemical affinity and E. M. F. than zinc, the theoretical weight of material required is even less; only one pound total of chlorine and magnesium are required per horse-power hour, with metallic sodium and free chlorine having a calculated E. M. F. of 4 volts it would only take about .8 pound per horse-power.

The easiest and best solution of the problem, however, does not seem to be the use of more powerful metals than zinc. The latter is powerful enough; it only takes, as we have seen, about one pound of it per h. p. hour with nitric acid, chromic acid or bichromate solution, and less than two pounds with copper sulphate. The opportunity for improvement seems to lie more in the direction of perfecting the general form of batteries. The *apparatus* is at fault, not the *chemical action*. Moreover, zinc

is about as high on the electro-positive scale as it is safe to go so long as water is present. Even in the case of zinc its affinity for oxygen is greater than that of hydrogen, it is therefore only by tolerance, so to speak, that zinc remains passive in the presence of water. If it is not properly amalgamated, or if the solution is too strong, local action does occur. If, in place of zinc, we use any more electro-positive metal these troubles are aggravated; with magnesium, for example, there are only very few solutions in which it will stand without great local action. Metals of still higher power, such as sodium, cannot be used at all in presence of water. Jablochkoff has, I believe, made cells in which sodium is used with damp cloth, but this can hardly be considered as water.

The proper way to use metals of great chemical energy would seem to be with liquids which do not contain any oxygen, but unfortunately such solutions are not generally good conductors. Another possible plan is to employ a fused electrolyte, but this involves the serious difficulty of maintaining it in the fused state.

So far as I can see, zinc is a very satisfactory positive material for batteries. After all it is cheaper than any other metal except iron. It is a sufficiently good conductor and less dirty and liable to corrosion than almost any other metal; it is also, as I have just shown, about as high on the electro-positive list as is safe to go.

The electro-negative materials on the other hand leave far more to be desired. They are generally expensive, very troublesome to handle, and introduce that quality of simple dirtiness, to which no other name can be applied, and which is really the most serious objection to batteries. The electro-negatives will, however, do the work, and as we have seen it actually requires very little weight to give it a great deal of power, if the materials could only be used in a more perfect manner than at present. That seems to be the thing to hope for. Another serious difficulty with batteries is their high internal resistance. A dynamo can easily be made to give 100 volts with a thousandth or a few ten thousandths of an ohm internal resistance, hence their great output; but a primary battery capable of giving 100 volts with only one thousand ohm internal resistance would probably fill this house.

In this connection it will be interresting to consider how many cells of ordinary gravity battery are required to give one horse-power of current. Each cell will give one volt and not more

than half an empère under normal conditions, hence each cell furnishes half a watt or about 1,500 cells to the horse-power! These cells would, however, give that power for a long time. But the fact remains that this very large number is required to produce the power which a dynamo not much larger than one's hat will generate.

In conclusion, I would say that I am by no means a skeptic in regard to chemical generators of electricity; the possibilities are very, very great, as I have shown. But these possibilities do not seem to have been brought to reality in a very perfect manner as yet. But batteries, even in the imperfect state in which they exist to-day, have their useful and legitimate function. A Leclanché cell is exceedingly well adapted to ringing electric bells intermittently and to telephone work, and gravity batteries have long done good service for telegraphic purposes.

But when it comes to developing any considerable amount of actual power, then the limitations become apparent. When we remember that battery electricity will certainly cost in practice 50 cents per horse-power hour, since the materials alone cost 25 cents, and that dynamo electricity only cost 2 cents per horse-power hour, the claims of some primary battery electric lighting promoters show up in their true light. As a luxury, of course, it makes very little difference what it costs, but even then people soon tire of paying very high prices for that kind of a luxury. For small electric lighting and small power in special cases batteries are useful, particularly where no other source of current is available. A physician or dentist to whom a horse-power hour may be worth hundreds of dollars could almost afford to use a chloride of silver battery and throw away the silver.

Mr. Crocker:—I do not wish to be understood as entirely skeptical in the matter of primary batteries. As I have said, the possibilities are almost infinite, but there are certain facts which cannot be overcome, which might as well be looked at straight in the face in the beginning, as after the company is formed and the failure occurs. There are certain legitimate applications of primary batteries even in their present state of imperfection. For example, the Leclanché battery is very satisfactory for ringing electric bells and for telephone work—we do not need a dynamo for those purposes—and even for small power uses, although I have not yet seen the battery which will practically generate electricity for actual power purposes at a reasonable

price. As a luxury a battery can be used, or for some very special purpose, like a dentist's or a physician's work, where a horse-power hour may be worth $1,000. There one could afford to use the silver-chloride battery and throw away the silver. (Applause.)

DISCUSSION.

DR. MOSES:—I think that we are very much indebted to Mr. Crocker for his able paper, and we cannot too highly laud the expenditure of time, the energy and self-abnegation devoted to preparing a paper of that character for the Institute. There are some questions he will permit me to ask him that will lead to others, and in that way to a useful debate. I notice that in this table D you have used chlorine, bromine and iodine for the three elements that you combine. Why did you select those whose atomic weights are perhaps less accurately determined, and which are not absolutely considered as elemental in their characer? Why did you not, perhaps, take oxygen or even carbon for the purpose?

MR. CROCKER:—In the first place, as I have said, oxygen pure and simple, does not combine directly with zinc in a battery. Free oxygen will dissolve only in the solution to a very limited extent, and it would, of course, be possible to use it, but only in a very delicate way. Whereas, bromine, chlorine and iodine will freely dissolve in the solution, and thus can be practically used in an elementary state. So far as the elementary character of bromine, chlorine and iodine is concerned, I have never heard it questioned before. If you mean that all so-called elements are not elements, and that hydrogen is really the only element, why, then, of course, these three go with the others, but, so far as I know, they stand on the same basis as carbon, oxygen and the rest; and, furthermore, they constitute a series, or family, of chemical elements. The results obtained are more clear and more instructive when a series of elements are used than when you take elements at random, such as the acids for instance, which are not exactly on the same basis. The real depolarizers are usually elements like chlorine, bromine and iodine. Chromic acid itself is not a depolarizer, it is the oxygen it contains. In that case it may be said that oxygen is employed as a depolarizer, but it is not free oxygen, it is in combination with chromide oxide, and therefore the question is complicated. It is, however, perfectly

possible to apply these same principles to any other chemical combinations, but it makes a more difficult problem, and the results are less clear.

Dr. Moses:—The figures are very conscientiously given, and the statement which Mr. Crocker makes that he puts down here a negative quantity simply because his galvanometer shows it, is a very acceptable statement, because he shows what he gets. Even the most inaccurate observations or results, if the methods are given, prove of equal value with the most accurate, as we recollect in the case of Vauquelin's analysis in the beginning of this century, though done in the most imperfect way, according to present methods, are very valuable, because he gives an account of how he did it. But there is a series of facts that are brought out by an inspection of the table and that rather tend to point to the moral that chlorine is itself not an element. I would like to recall to Mr. Crocker's attention the fact that the very discoverer of chlorine doubted its elemental character for a very long time, and it is to-day a mooted question whether it is a simple element. You have in that table a series of comparisons in which you find, with but one exception, that the determination is less than the calculated one. I will read them: 3.24, 3.1; 2.9, 2.11; 2.19; 2.3, 2; 1.75, 1.6; 1.64, 1.43; 1.57, 1.43; 1.71, 1.61; 1.76, 1.63; 1.4, 1.32; 1.25, 1.11; 1.3, 1.22; 1.3, 1.21. That shows of itself there is a certain law there; it shows that perhaps you should assume a lower chemical equivalent for chlorine.

Would you also tell us why you prefer not to determine accurately the amount of water that you used for solution? Don't you find, since water is essential, that its chemical equivalent and its relations to the substances in solution should be just as accurately determined, though we are inclined to consider a solution is not a chemical combination? Still, for these purposes the elements go through combinations through the solution. Therefore, why isn't it essential to determine the water?

Mr. Crocker:—The water is merely a medium for the action to take place in; that is really the chemical fact. Of course I could put there, in the case of the weights, about how much water an ordinary solution would require; but that really would be merely guesswork. The best you could do would be to find when you obtained the maximum results, and that would be a very difficult question, but I find that it makes very little difference in electromotive force whether a strong or a weak solution

is used. It does make some difference. The stronger the solution, the less the electromotive force. The difference amounts to about 5/100 or 1/10 of a volt. This is because there is more tendency for the metal to go in solution when the latter is weak; whereas if the solution is already satisfied it has less affinity for the metal. That is the way I explain the fact. I intended to bring out this point in my paper, but it involves another series of experiments, and the ones I have given were all that I had time to undertake.

Dr. Vander Weyde:—Is it not the fact that a certain concentration of a solution gives the least resistance? We all know that, for instance, a mixture of sulphuric acid and water of a certain proportion is the best conductor. If we increase the water or the sulphuric acid the resistance becomes greater.

In the meantime, Mr. President, while I am up, I cannot refrain from paying a compliment to Mr. Crocker (applause) for his very useful labor, It was just the thing that was needed, and I rejoice that the young man goes in the right direction. It is an investigation in which I had been engaged myself some years ago, intending to publish some data, but other business intervened and I found the field so extensive that I despaired of making it as complete as Mr. Crocker has done. (Applause.)

I wish to make one remark about the function of water in the battery. I would like to hear Mr. Crocker's opinion about a widely adopted theory that the water is the main agent in the batteries—that it is the decomposition of the water which does the work; that the oxygen of the water combines with the zinc and that hydrogen is developed, and a layer is formed which is the cause of polarization, and in order to get rid of that hydrogen the depolarizers are applied. I would like to hear Mr. Crocker's opinion about that theory.

Mr. Crocker:—As regards the function of the water in the battery it is one of those metaphysical points. (Laughter.) The water may act and give up its oxygen. The hydrogen may give up the oxygen on one side and turn around and get more on the other side. So far as I can see, it is water all the time. It is not changed, and it acts as a transmitter; that is the most it does. It acts as a vehicle. But after the action is over, there is just as much water there as there was before, unless it has evaporated; and in fact some chemical actions involved in batteries produce water, and in that case there would be more water at the end of

the action than there was at the beginning. Therefore, it could hardly be said that it was used up. Furthermore, the action would take place exactly the same in the anhydrous state, whenever it is possible to get that state. For example, with a fused salt the action is exactly the same. The zinc would combine with chlorine in fused chloride of zinc, as I have myself proved by experiment, and would give substantially the same electromotive force as it does in the presence of water. Water is merely a means of getting a liquid conductor, which it is necessary to have as an electrolyte. An electrolyte must be a liquid, and you can obtain the liquids by fusing a solid electrolyte, or by dissolving a solid electrolyte. Therefore I always look upon the water merely as a means, or medium, in which the action takes place.

DR. VANDER WEYDE:—But the question naturally follows that if the zinc is oxydized by the oxygen what becomes of the hydrogen at the point of contact with the oxygen? Then there is more than a mere vehicle. We see that the hydrogen is developed at the platinum or silver plate.

PROF. NICHOLS:—I would like to supplement Mr. Crocker's statement by an observation in reference to the behavior of iron, and I presume what is true of iron will be true of other metals which form two salts. If you take iron and platinum in a solution which will produce a ferric salt, and let the cell stand, so that the iron in solution becomes surrounded with a film of its own salt, then the ferric action will gradually cease and ferrous action will take place. After the cell has stood, the electromotive force will rise about one-fifth, and you can instantly restore it to the condition it had at first. If you take a porous cell and separate the iron and platinum, put the oxidized solution in connection with platinum and then around the iron something which will produce the ferrous salt, you will find that that battery has about one-fifth more electromotive force than in the case of the ferric combination. It seems as though a more successful battery ought to be made with iron producing the ferrous salts. You gain almost enough to make up the difference between iron and zinc; but the behavior of iron is very unsatisfactory, and the reasons for it are not always very clear. It seems as though oftentimes it was due to the formation of oxidized films which run the resistance of the cells up to an enormous height. I have known the resistance of bichromate cells with iron positive plates to run up to several hundred ohms in the course of an hour or so by the formation, apparently, of an insoluble film of some form of iron

which was almost a non-conductor. Perhaps iron, if worked out patiently, might give us a very cheap metal for a pole of a battery which would reduce the cost of galvanic electricity very considerably.

Dr. Vander Weyde:—I want to say in respect to silver being an electro-negative, that Mr. Crocker is perfectly right in that.

Dr. Moses:—The remarks of Prof. Nichols recall to my mind some experiments which he perhaps has overlooked, but which he made quite a number of years ago, in which he used, if my memory serves, zinc in a sulphate of copper solution, where the change of temperatures produced considerable variations. I would like to inquire whether that was not due to the formation of salts of variable solubility around the electrode.

Mr. Nichols:—It might very easily be.

Mr. Mailloux:—I would like to ask what appears to be a somewhat pertinent question in view of the discrepancy observed between the calculated and determined electromotive force, and that is as to the standard which Mr. Crocker used; what value he accepted for it, and upon what authority, so that we may know what kind of a volt he employed.

Mr. Crocker:—That is an important point, of course, because everything depends upon it. I used constant Daniell cells, two independent ones set up separately, with chemically pure sulphate of zinc and sulphate of copper, and chemically pure metals; the solutions were half saturated. Then I further checked the results by two electromotive forces which I happened to know and had previously determined very many times, and those are the bromide and the iodide combination of zinc. The former combination in itself is an excellent standard cell, that is, free bromine and zinc. It gives an electromotive force of 1.79 volts. That is the result, I suppose, of a thousand experiments carried on with a certain object. Therefore in going through my experiments when I came to the combination zinc-bromide and found that it gave an electromotive force of 1.79 volts, I felt perfectly at home, because I had been there so often before, and it corroborated by standard. Then the combination of zinc and chlorine, 2.11 volts has also been very frequently determined. In the case of the Upward (zinc-chlorine) battery, which came out about a year and a half ago in England, the published electromotive force was 2.11 volts. So there were several corroborative facts. So far as my experience goes, a standard Daniell cell does not vary very much in electromotive force.

PROF. THOMSON:—I would like to say just one word on this subject. It has been probably a common experience of those having Daniell cells in operation, that, if the solution is not kept up to a high degree of strength, oftentimes the upper part of the copper will be eaten out, and an electrolytic deposit of the copper made in the lower part of the cell where the solution is strong; or, in other words, here is an indication of a difference in the volts which carries on a sort of plating action on the copper plate itself. Whether this be due partly to the effect of the acid, or that the solution comes through from the porous cup and floats on top, causing a difference in the electrolytic condition of the fluids alone, setting up current, I do not know. But it recalls to my mind an observation several years ago on the effect of simple heating of the solution by putting at the lower part of a test tube a little spiral of copper wire and carrying out a connection by an insulated wire from the spiral, filling up the test tube partly with sulphate of copper solution; putting another little spiral near the top of the fluid, and then heating, we find a difference of voltage, and it amounts, I think, to something over one-tenth of a volt, or rather, something over one-twentieth of a volt, if I remember the result of the experiments correctly; showing that a solution of the copper will take place in the hot liquid, and a deposition of the copper in the cold liquid. In other words, the hot liquid is more of a solvent than the cold, although it is a sulphate of copper solution throughout. Whether Mr. Crocker has taken into account the temperature of the solutions in making these tests I do not know.

MR. CROCKER:—I made the tests at the normal temperature. It did not vary 5 degrees from 68; I do not think it varied more then three or four degrees. What Prof. Thomson says about a hot liquid giving electromotive force with a cold liquid, as it were, is true. In fact, Mr. Bradley has a battery which works on that principle, giving quite an electromotive force; I could not say exactly what, but quite a fraction of a volt, and it depends, to a certain extent, upon the heat of the solution; and that is a very interesting and possibly a productive field for investigation.

PROF. THOMSON:—There is another point and then I am through. It is probably well understood nowadays that all the elements are not to be considered as real elements as we find them. I do not mean that they are decomposable into hydrogen,

although I think that quite possible, and perhaps even to a far more primitive condition than hydrogen, if we could use forces which we have not at hand—I mean the celestial forces. I mean that each particle of copper known to us is a combination of copper with copper; that the atom really forms a molecule which is a real compound. Two atoms or more atoms may be found united, but it will certainly take something to decompose those molecules, even though they be combinations of the same atoms. I am struck with the results obtained with aluminium in the work of Mr. Crocker. We find actually that this metal, so hard to get at, is really capable of giving an electromotive force less than zinc; so that it would seem as though by the proper use of zinc in some way or other we might separate aluminium. In other words, its electromotive energy is very much less than zinc, and in some cases not very much different from iron. In the recently developed reduction of aluminium we find that carbon at high temperature reduced it with comparative facility, and it may be that after all, we have only to find, something which will fluidize or liquify the aluminium, and we would then find that even common materials like zinc or iron would separate from these combinations.

Mr. Crocker:—In regard to aluminium, the same thing struck me that Prof. Thomson points out. By my experiments aluminium is apparently less electro-positive than zinc. I do not think that this is actually the fact. I think there is some loss of electromotive force which occurs. In fact the calculated results are higher than those of zinc, and it may be that with aluminium there is a formation of insoluble compound on the plate. I am quite certain that my observed electromotive forces, although they are the actual electromotive forces given by a good piece of aluminium, are lower than the theoretical and lower than the possible electromotive force.

Dr. Vander Weyde:—It may be useful to state here that twenty years ago I attempted to substitute aluminium for platinum in the Grove battery, on the principle that nitric acid does not attack platinum. The result was negative. I got scarcely any current at all. It appeared that aluminium had not the power to decompose the nitric acid and produce the nitrous acid fumes as with platinum in the Grove battery. It was a very carefully made experiment and impressed me very much.

Note.—The continuation of the Transactions of the General meeting will follow in the July number.

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OF

CURRENT ELECTRICAL LITERATURE,

&c. (April, 1888.)

TELEGRAPHY.

The Probable Durability of Hard-drawn Copper Telegraph Wire. Wm. Maver, Jr. *N. Y. Elec. Engr.*, April, p. 157.

Favorable results of a four years' telegraphic use of the wire, which the writer believes likely to find more general use than at present.

Long Distance Telegraphy. *Elec. World*, April 21, p. 201.

Telegraphic Communication between China and Europe. *Lond. Elecn*, April 13, p 627.

Modern Military Appliances. (Ill.) *Illust. Zeitung; Sci. Am.*, April 21, p. 246.

A very interesting article on military telegraphs, etc.

The First Appropriation of Congress for the Telegraph. *Sci. Am.*, April 28, p. 265.

Sir John Pender. (With Portrait.) *Lond. Elecn.*, April 27, p. 687. Banquet. April 27, p. 706.

Synchronous Multiplex Telegraphy. (Ill.) (Corr.) P. B. Delany. *Lond. Elecn.*, April 27, p. 714.

Train Telegraphy. *Sci. Am.; Lond. Elecn.*, April 27, p. 684; *Lond. Elec. Engr.*, (The Lehigh Valley R. R.) April 6, p. 315.

The Government Telegraph Bill. (Ed.) *Md. Lt. & Ht.*, April 19, p. 437.

Effect of Relays in Circuit. (Corr.) *Elec. World*, April 7, p. 180.

Telegraphic Lightning Dischargers. *Annales Telegraphiques; N. Y. Elec. Rev.*, April 28, p. 7.

Monkeys on Telegraph Wires. (Note.) *Lond. Elec. Engr.*, April 27, p. 386. (Mexico.)

Telegraph Keys. (Ill.) *N. Y. Elec. Rev.*, April 21, p. 6. (West Electric.)

New Telegraph Key and Sounder. (Ill.) *N. Y. Elec. Rev.* April 28, p. 6. (The "Unique," New Haven Clock Co.)

The Writing Telegraph. (Ill.) *Prac. Elec.*, April, p. 203. (J. H. Robertson.)

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Fire Telegraphy and False Alarms. *Lond. Elec. Rev.*, April 20, p. 411. R. von Fischer-Treuenfeld, Soc. Tel. Engrs. and Elecns. (Corr.) F. Higgins. April 27, p. 464.

The New York Fire Telegraphs. (Ill.) *Indust.*, April 20, p. 405.

New Automatic Fire Alarm. (Ill.) *Lond. Elecn.*, April 27, p. 711.

Electrical Alarm Clock. (Ill.) *West. Elecn.*, April 21, p. 193. (Dennison-Hall Mfg. Co., Chicago.)

An alarm clock combined with battery. The switch must be turned before the ringing ceases.

New Watchman's Clock. (Ill.) (New Haven Clock Co.) *N. Y. Elec. Rev.*, April 14, p. 1; *Elec. World*, April 21, p. 200.

A Dial Annunciator. (Ill.) *Elec. World*, April 21, p. 200.

A Simple Alarm. (Ill.) (Corr.) W. E. Kauke. *Elec. World*, April 21, p. 198.

A Novel Electric Train Signal. (Ill.) *Md. Lt. & Ht.*, April 26, p. 464.

The "Acme" appliance replacing the ordinary bell rope.

Optical Telegraphy. *Eng.*, April 13, p. 370.

The American Inventors of the Telegraph. F. L. Pope. *Century*, April, p. 924.

Dealing specially with the work done by Alfred Vail, as inventor of the spring finger key, proposer of an alphabetical code, etc.

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Practical Telephony. (Ill.) Thos. D. Lockwood. Part VIII. *West. Elecn.*, April 21, p. 195.

Kansas City Telephone Exchange. *West. Elecn.*, April 7, p. 177.

The Chicago Cushman Telephone Company. *West. Elecn.*, April 14, p. 181.

The Telephone in Peru. (Note) *Lond. Elec. Engr.*, April 6, p. 313.

The Telephone in Europe. *N. Y. Elec. Rev.*, April 7, p. 6. (Statistics.)

The Telephone in Mexico. *Elec. World*, April 28. p. 217.

The Telephonic Bullet Probe. (Ill.) John H. Girdner. *N. Y. Elec. Rev.*, April 28, p. 1; *Proc. Elec.*, April, p. 204.

To Find a Ball in the Human Body. *N. Y. Elec. Rev.*, April 7, p. 5; April 14, p. 1.

Application of the Telephone. *N. Y. Elec. Rev.*, April 14, p. 1. (Ader.

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A Sound Receiver for Submarine Telegraph Lines. *Lond. Elecn.*; *N. Y. Elec. Rev.*, April 21, p. 7; *Lond. Elec. Engr.*, April 6, p 314 (Ader).

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Telephone Systems. (Corr.) F. B. O. Hawes. *Lond. Elecn.*, April 27, p. 720.

The Rise and Progress of Telephony in the United Kingdom. (Ill.) (Cont'd from p. 537.) *Lond. Elecn.*, April 27, p. 687.

A Proposed New Public Telephone System for Cities and Large Towns. (Ill.) Walker Moseley. (Cont'd from p. 542.) *Lond. Elecn.*, April 13, p. 624.

The Bell Company's Report. (Ed.) *N. Y. Elec. Rev.*, April 7. p. 4.

The Government and the Telephone. *Lond. Elec. Rev.*, April 20, p. 413.

How to Make the Telephone Transmitter More Convenient. (Note.) *N. Y. Elec. Rev.*, April 7, p. 5.

Alleged Antiquity of the Telephone. *N. Y. Elec. Rev.*, April 7, p. 1. (India.)

The Report of the American Bell Telephone Company. *N. Y. Elec. Rev.*, April 7, p. 6; *Elec. World*, April 7, p. 179; *N. Y. Elec. Engr.*, April, p. 188.

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An Opinion on the Bell Telephone Suits. (Corr.) "Electron." *Md. Lt. & Ht.*, April 5, p. 379.

The Bell Telephone before the American Courts. *Indust.*, April 13, p. 377.

Judgment of the Supreme Court of the United States in the Telephone Appeals. *Lond. Elecn.*, April 6, p. 607; April 13, p. 640; April 20, p. 668.

The Telephone Decision in Brief. *N. Y. Elec. Engr.*, April, p. 182.

A Victory for the Patent Law. (Ed.) *N. Y. Elec. Engr.*, April, p. 153. Review of the Bell Telephone decision.

About Microphone Receivers. (Ill.) (Corr.) C. J. Kintner. *N. Y. Elec. Rev.*, April 28, p. 3.

The Future of the Phonograph. *N. Y. Elec. Rev.*, April 21, p. 1. (Humorously presented by J. Armoy Knox.)

The Telephone as a Galvanometer in Bridge Measurements. (Ill.) *N. Y. Elec. Rev.*, April 14, p. 7. (Lovett.)

An Electric Ore Tester. (Ill.) *Elec. World*, April 21, p. 198. Telephonic apparatus having a brush in circuit, which as it passes over ore, or ground with metal in it, is supposed to give a click in the telephone at every metallic contact.

The Caloriphone. Léon de Pontois. *Elec. World*, April 7, p. 175.
The object of this apparatus is to obtain telephonic communication without the use of a conducting wire, between comparatively distant stations.

ELECTRIC LIGHT.

How to Look at an Arc Lamp and What We May Expect to See. *Md. Lt. & Ht.*, April 19, p. 442.
An investigation as to lighting values, and the meaning of "candle power."

Zone of Maximum Intensity in Arc Light. *Elec. World*, April 21, p. 201.

The Maximum Efficiency of Incandescent Lamps. (Ill.) John W. Howell. Am. Ins. Elec. Engrs. *Elec. World*, April 14, p. 190.
Discussion on the above April 28, p. 217. *Md. Lt. & Ht.*, April 12, p. 410. *West. Elecn.*, April 14, p. 183. *Science*, April 20, p. 188.

The Edison Glow Lamp Patents. *Indust.*, April 27, p. 428.

Incandescent Lamp Patents. *Lond. Elec. Rev.*, April 27, p. 450; *Lond. Elecn.*, April 20, p. 663; April 27, p. 698.
(Edison & Swan United Electric Light Co. *v.* Holland and Others.)

High Candle-Power Incandescent Lamps. *Science*, April 13, p. 177.

A 1,000 c. p. Incandescent Lamp. (Ill.) *Elec. World*, April 7, p. 179.
Lamps of 100 volts and 20 amperes employed in the work at the Forth Bridge, Scotland. The lamps of 800 c. p. have a single loop; those of 1,000 c. p. have two filaments in parallel, kept apart by a cleat-like device fused in the bottom of the bulb.

Incandescence Filaments. (Note.) *Lond. Elec. Engr.; Lond. Elec. Rev.*, April 27, p. 446. (Note.) *Lond. Elec. Engr.*, April 20, p. 364.

The Size of Incandescent Lamp Filaments. *L'Electricien; La Lum. Elec.; Lond. Elecn.*, April 13, p 633.

A Diagram Showing the Size of Conductors for House Wiring. (Ill.) C. H. Crockett. *Elec. World*, April 21, p. 202.
Gives size for wiring with Edison 16 c. p. lamps, 100 volts, .75 ampere, with 1 per cent. loss in conductors.

Insulating Electric Light Conductors. (Corr.) W. M. C. *Lond. Elec. Rev.*, April 13, p. 407.

Insulating Electric Light Conductors. (Corr.) S. A. Russell. *Lond. Elec. Rev.*, April 27, p. 463.

Thomson-Houston and the La Salle St. Tunnel. (Ill.) *West. Elecn.*, April 21, p. 194.
Method of lighting up tunnel under the Chicago river. A Thomson motor is also used to drive a ventilating fan.

Chicago River Lighting Plant. (Ill.) *West. Elecn.*, April 14, p. 182.
A Western Electric plant of 120 arc light capacity installed by the City of Chicago to facilitate navigation of the Chicago river at night.

The Heisler Plant at Matteawan. (Ill.) *West. Elecn.*, April 7, p. 173.

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The Electric Light Plant in the Amphion Academy, Brooklyn. (Ill.) *Elec. World*, April 21, p. 199. (Edison installation)

The Brush Electric Light Station at Rochester, N. Y. (Ill.) *Elec. World*, April 14, p. 187.

A fine station of 1,100 arcs, 1,000 incandescents, and nearly 200 motors operated by water-power from the Lower Genesee Falls.

Electric Lighting of Spanish Theatres. *Lond. Elecn.*, April 13, p. 621.

The Arc Light Installation of the International Jubilee Exhibition of Fine Arts in Vienna. (Ill.) *Lond. Elecn.*, April 6, p. 596.

The Relative Cost of Gas, Oil and Electricity in Russia. *Lond. Elecn.*, April 13, p. 621.

Navigating the Suez Canal by Night. (Note.) *Lond. Elec. Rev.*, April 6, p. 370. (Note.) *Lond. Elec. Engr.*, April 6, p. 317.

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Saint Etienne Central Lighting Station. (Ill.) Fontaine. *Lond. Elec. Engr.*, April 20, p. 366.

Electric Lighting at the Victoria Hotel, Manchester, Eng. *Indust.*, April 27, p. 430.

The Southampton Sewage Works. (Ill,) *Indust.*, April 20, p. 408.

The proposed use of sewage as fuel for a city electric lighting plant.

Electric Lighting at the Glasgow International Exhibition, 1888. (Ill.) *Indust.*, April 20, p. 396.

Lighting the Union Bank of London. *Lond. Elec. Rev.*, April 6, p. 359; *Lond. Elec. Engr.*, April 6, p. 321.

Travelling Arc Installation for Railways. (Ill.) *Centralblatt für Elektrotechnik; Lond. Elec. Engr.*, April 20, p. 370.

On the Cost of Central Station Lighting. (Corr.) J. K. D. Mackenzie. *Indust.*, April 20, p. 403.

The Cost of Central Station Lighting. R. E. B. Crompton. *Indust.; West. Elecn.*, April 14, p. 187; *Indust.*, April 20, p. 405.

Central Station Lighting by Storage Batteries. *Indust.; West. Elecn.*, April 14, p. 181.

Power for Lighting from an Artesian Well. H. B. Rockwood. *Sci. Am.; West. Elecn.*, April 7, p. 177.

Water-Power and Electric Lighting. (Note.) *Lond. Elec. Rev.*, April 6, p. 368.

Lord Crawford's Electric Lighting Bill. *Lond. Elec. Rev.*, April 20, p. 415.

Electric Lighting Act (1882) Amendment Bill. *Lond. Elec. Engr.*, April 20, p. 380; April 27, p. 404.

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Electric Light Signalling by Reflection from Clouds. *Lond. Elecn.*, April 27, p. 684.

Carbons for Arc Lamps. (Note.) *Lond. Elec. Rev*, April 6, p. 369. (Note.) *Lond. Elec. Engr.*, April 6, p. 315; April 27, p. 386. (Hardtmuth.)

A New Absolute Cut-Out. (Ill.) *Md. Lt. & Ht.*, April 26, p. 464; *N. Y. Elec. Rev.*, April 28, p. 8. (Thomson-Houston.)

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Waterhouse Electric Light Company. *Hartford Courant; West. Elecn.*, April 14, p. 189.

A Device for Testing Arc Light Circuits to Discover Leaks to Earth. (Ill.) C. H. Rudd. *West. Elecn.*, April 21, p. 196. (Chic. Elec. Club.)

The New Gas Attachment. (Ill.) *West. Elecn*, April 7, p. 171.
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Lamp Holder. (Ill.) *Lond. Elec. Engr.*, April 20, p. 376. (Woodhouse-Rawson.)

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The Electric Light in Textile Manufactories. (Note.) *Cent. für Elek..; Lond. Elec. Engr.*, April 13, p. 338.

The Use of Electricity for Theatre Lighting. *Lond. Elecn.*, April 27, p. 712. Soc. Tel. Engrs. and Elecns. (E. G. Tidd.) *Lond. Elec. Engr.*, April 27, p. 390; *Indust.*, April 6, p. 357.

The Electric Lighting of Theatres. *N. Y. Elec. Rev.*, April 28, p. 5.

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Train Lighting. (Note.) *Lond. Elec. Rev.*, April 20, p. 418. (K. Hedges) (Note.) *Lond. Elec. Engr.*, April 13, p. 341.

Navigation Projector. (Ill.) *Lond. Elec. Rev.*, April 27, p. 436. (Paterson & Cooper.)

The Electric Light and Naval Warfare. (Note.) *Lond. Elec. Rev.*, April 27, p 444

Portable Electric Lighting Apparatus. (Note.) *Lond, Elec. Engr.*, April 20, p. 364. (Ganz & Co., of Buda-Pesth)

The Electrical Odontoscope. (Ill.) *Sci. Am. Supp.*, April 21, p. 10,260.

Trouve's Anxanoscope. (Note.) *Lond. Elec. Engr.*, April 20, p. 361; *Sci. Am. Supp.* (Ill.), April 7, p. 10,225.

Why Profits Dwindle. D. C. Jackson. *N. Y. Elec. Engr.*, April, p. 160. A very interesting and significant statement of the manner in which electric light stations can be operated at a loss, without effort.

Future Gas Companies. *West. Elecn.*, April 21, p 200. (T. Wood, Ohio Gas Lt. Assn.)

Gas Companies and the Electric Light. *Gas World; West. Elecn.*, April 14, p. 183.

Illumination. (Note.) *Lond. Elec. Engr.*, April 20, p. 363. (Hospitalier.)

Photometry. *Lond. Elec. Engr.*, April 20, p. 376.

Harcourt's Pentane Standard Lamp. (Ill.) *Lond. Elec. Rev.*, April 6, p. 358. (A. Vernon Harcourt.) *West. Elecn.*, April 14, p. 182.

The Development of the Mercurial Air Pump. (Ill.) S. P. Thompson. *N. Y. Elec. Engr.*, April, p. 169. (Lond. Soc. Arts.)

The Application of Electricity to Lighting and Working. (Ill.) W. H. Preece. *Lond. Elecn.*, April 27, p. 690. (Juvenile Lectures, Soc. Arts.)

An Early Inventor in Electric Lighting. *Pall Mall Gaz.; Lond. Elecn.*, April 20, p. 653. (Starr.)

The Formation of the New England Electric Exchange. *Md. Lt. & Ht.*, April 5, p 390; April 12, pp. 407–415; *N. Y. Elec. Rev.*, April 7, p. 9; April 21, p. 2; *Elec. World*, April 14, p. 192; April 21, p 198.

The Electric Light and Fire Losses. (Ed.) *Md. Lt & Ht.*, April 19, p. 437.

Fire Office Rules. *Eng.*, April 13, p. 369.

Relating to Incandescent Lighting. *N. Y. Elec. Rev*, April 14, p. 2. (Rules of New Eng. Ins. Ex.)

How Insurance Men Appreciate the Electric Light. *N. Y. Elec. Rev.*, April 14, p. 10.

Rules for Electric Light Installation. *Elec. World*, April 21, p. 202. (New Eng. Ins. Ex.) Arc and incandescent.

Reduced Rates of Insurance on Property Lighted by Electricity. *Md. Lt. & Ht.*, April 5, p. 382; *Elec. World*, April 14, p. 186.

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Soc. of Tel. Engrs and Elecns. Rules and Regulations for the Prevention of Fire Risks arising from Electric Lighting.

The Electric Light Convention. *Eng.*, April 6, p. 340. (Pittsburgh meeting.)

Cunynghame, Woodhouse & Rawson Magnetic Cut-Out. (Ill.) *Lond. Elecn.*, April 20, p. 670.

DYNAMOS, SYSTEMS OF DISTRIBUTION, &c.

Experiments Illustrating the Principle of the Dynamo. G. M. Hopkins. (Ill.) *Sci. Am.*, April 14, p. 233; April 21, p. 244; *Lond. Elec. Engr.*, April 27, p. 398.

The Coupling of Alternating Current Dynamos in Parallel. (Ill.) Dr. G. Stern. *Lond. Elec. Rev.*; *Elec. World*, April 7, p. 174.

Electrical Welding. (Note.) *Lond. Elec. Rev.*, April 13, p. 402. Prof. A. E. Dolbear in *Am. Eng. Record.* (Note) *Lond. Elec. Engr.*, April 6, p. 314; *N. Y. Elec. Rev.*, April 7, pp. 2, 7.

A New Induction Coil. (Ill.) *West. Elecn.*, April 28, p. 209 (E. E. Ries.)

A New Form of Induction Coil. (Ill.) *Elec. World*, April 28, p. 214. (Elias E. Ries.)

In this type of transformer the high tension primary wire is completely inclosed within and protected by the low tension secondary, the two forming a single compound conductor.

Experiments on Induction Coils. II. (Ill.) Dr. Louis Duncan, Cary T. Hutchinson & Gilbert Wilkes. *Elec. World*, April 28, p. 212.

The Lag in Transformers. W. E. Ayrton and J. Perry. *Elec. World*, April 14, p. 187.

Alternating Current Transformers. (Corr.) *Lond. Elecn.*, April 20, p. 671; April 27, p. 721; *West. Elecn.*, April 14, p. 182.

Formulæ for Transformers. Prof Geo. Forbes. *N. Y. Elec. Engr.*, April, p. 160. (Soc. Tel. Engrs. & Elecns.)

The Counter-Electromotive Force of Transformers, or Converters. *Md. Lt. & Ht.*; *N. Y. Elec. Engr.*, April, p. 181.

The Comparative Value of the Continuous and the Alternating Current Systems for the Commercial Distribution of Electricity. M. M. M. Slattery, Chic. Elec. Club. *Prac. Elec.*, April, p. 207.

Comparative Value of Continuous and Alternating Current Systems for the Commercial Distribution of Electricity. (Ill.) H. Ward Leonard, Chicago Elec. Club. *Lond. Elecn.*, April 6, p. 604; *N. Y. Elec. Engr.*, April, p. 166.

The Comparative Value of the Alternating Transformer and Continuous Current Systems for Central Station Lighting. F. B. Badt, Chic. Elec. Club. *West. Elecn.*, April 28, pp. 205–208.

Comparative Value of the Converter and Continuous Current Systems of Electrical Distribution. (Ill.) E. P. Warner, Chic. Elec. Club. *N. Y. Elec. Rev.*, April 14, p. 8; *West. Elecn.*, April 7, p. 175.

The Alternate vs. the Continuous Current. (Corr.) T. Carpenter Smith, Nat. Elec. Lt. Assn. *N. Y. Elec. Engr.*, April, p. 180.

Central Station Lighting: Transformers vs. Accumulators. (Ill.) R. E. B. Crompton, Soc. Tel. Engrs. and Elecns. *Lond. Elec. Rev.*, April 20, p. 424; April 27, p. 456; (Note.) April 13, p. 402; (Ed.) April 27, p. 433; *Lond. Elecn.*, April 13, p. 634; April 20, p. 655; April 27, p. 694; *Lond. Elec. Engr.*, April 13, p. 342; April 20, p. 378; April 27, p. 403. *Science*, April 27, p. 200; *Eng.*, April 20, p. 392.

Electrical Distribution by Means of Transformers. III. K. D. Mackenzie, Soc. Tel. Engrs. and Elecns. *West. Elecn.*, April 14, p. 189.

The Alternating vs. the Continuous Current System. *West. Elecn.*, April 14, p. 188; April 21, p. 201; *Science*, April 6, p. 167.
(Discussion on Kapp & Mackenzie's paper. Soc. Tel. Engrs. and Elecns.)

On Alternate Current Transformers, with Special Reference to the Best Proportion between Iron and Copper. (Ill.) Gisbert Kapp. *N. Y. Elec. Engr.*, April, p. 161. (Soc. Tel. Engrs. and Elecns.) Discussion, p. 176.

Continuous Current Transformation. R. P. Sellon. *Lond. Elecn.*, April 13, p. 623.

Notes on Alternate Currents. (Ill.) J. A. Fleming. *Lond. Elecn.*, April 6, p. 591; April 20, p. 654.

The Problem of Electrical Distribution. (Ed.) *N. Y. Elec. Engr.*, April, p. 154.
Discussion of the alternating *versus* the direct method.

Application of Electric Converters. *Eng.*, April 13, p. 370. (Wm. Stanley.)

Fein's Multipolar Dynamo. (Ill.) *N. Y. Elec. Rev.*, April 7, p. 3.

The Eickemeyer Dynamo. (Ill.) *Elec. World*, April 28, p. 213.
The completed form of the commercial "ironclad" dynamo.

The Mayo Incandescent Dynamo. (Ill.) (V. J. Mayo.) *Elec. World*, April 7, p. 175.

The Thone Dynamo. (Ill.) (F. Thone) *Elec. World*, April 7, p. 179.

Machine for Winding Dynamos. (Ill.) *Lond. Elec. Engr.*, April 13, p. 347. (Special lathe designed by Wilkinson and Lister for dynamo winding.)

Some Points in the Mechanical Construction of Dynamos. *Lond. Elec. Engr.*, April 6, p. 318. (See p. 78, Jan. 27, for previous article.)

Note on the Theory of Dynamo Machines. *Ann. Phys. und Chem.; N. Y. Elec. Rev.*, April 28, p. 1.

A Practical Method of Calculating and Designing Dynamos and Motors. (Ill.) F. B. Crocker, N. Y. Elec. Soc. *Elec. World*, April 28, p. 215.

The Magnetic Circuit of Dynamo Machines. (Ill.) (Corr.) H. W. Ravenshaw. *Indust.*, April 6, p. 351.

Dynamo Efficiency. *Lond. Elec. Engr.; Prac. Elec.*, April, p. 211.

Kapp or Silvey? (Corr.) Gisbert Kapp. *Elec. World*, April 14, p. 186.

Mr. Silvey on His Defense. (Corr.) W. L. Silvey. *Elec. World*, April 28, p. 212.

"Built-Up" Dynamo Plants. (Ill. Corr.) Ewing McLean. *Elec. World*, April 2, p. 198.

The E. M. F. of Disc Dynamos. (Corr.) *Elec. World*, April 7, p. 180.

The Output of Dynamos per Unit Weight of Copper. *Zeits. für Elect.; Lond. Elecn.*, April 13, p. 634. M. W. Peukert.

The Magnetic Circuit of Dynamo Machines. (Note.) H. W. Ravenshaw. *Indust.; Lond. Elec. Rev.*, April 13, p. 403.

The Direct Optical Projection of Electro-Dynamic Lines of Force, and other Electro-Dynamic Phenomena. (Ill.) J. W. Moore. *Sci. Am. Supp.*, April 21, p. 10,256.

ELECTRIC POWER.

Organ Blowing by Electricity. (Note.) *Lond. Elec. Engr.*, April 27, p. 389.

Electric Fan Outfit. (Ill.) *Prac. Elec.*, April, p. 210. (With C. & C. motor.

Stamping Bills and other Documents by the Electric Motor. (Ill.) *Elec. World*, April 7, p. 175; *N. Y. Elec. Rev.*, April 7, p. 1; *Prac. Elec.*, April, p. 210.

C. & C. motor operating the stamping apparatus of the Adams Express Company.

Manufacturing Jewelry by Electric Power. (Ill.) *Elec. World*, April 7, p. 176.

Use of Sprague motor in a jewelry factory in New York.

Simple Electric Motor. (Ill.) *Lond. Elec. Rev.*, April 13, p. 390. (Geo. M. Hopkins.) *Sci. Am.*

How to Make a Simple Electric Motor. (Ill.) Geo. M. Hopkins. *Sci. Am. Supp.*, April 14, p. 10,240.

Electric Motors in America. (Note.) *Lond. Elec. Rev.*, April 6, p. 371.

Electric Transmission of Power by Brown's Dynamos. (Ill.) *Eng.*, April 20, p. 380.

Electric Motors for Mining Work. *Science*, April 6, p. 168.

Utilization of Electricity in South Wales Mining Operations. *Lond. Elecn.*, April 6, p. 604. (Electric Shot Firing, Lighting and Signaling. *Iron and Coal Trades Review.*)

An Extensive Application of the Electrical Transmission of Power. (Ill.) *N. Y. Elec. Rev.*, April 7, p. 8. (Sprague motor in California mining.)

Electric Coal Cutting Machine. *Lond. Elecn.*, April 6, p. 589; *N. Y. Elec. Rev.*, April 14, p. 10; *Elec. World*, April 28, p. 217.

Pumping in Mines by Electricity. *Indust.; N. Y. Elec. Rev.*, April 28, p. 9; *West. Elecn.*, April 21, p. 194.

Constant Current and Constant Potential Motors in Practice. J. A. Powers. *N. Y. Elec. Engr.*, April, p. 158.

A broad treatment of the electric power question, with reasons for the more general introduction of series motors.

The Krebs Electric Motor. *Lond. Elec. Engr.*, April 13, p. 339.

A New Electric Launch. (Note.) *Lond. Elec. Engr.*, April 6, p. 314.

The Electric Launch "Lady Cooper." (Ill.) *Lond. Elecn.*, April 13, p. 627.

The Elieson Motor. *N. Y. Elec. Rev.*, April 28, p. 6.

Electrical Tramways: The Bessbrook and Newry Tramway. (Ill.) Ed. Hopkinson. *Lond. Elec. Engr.*, April 13, p. 353; April 20, p. 376; April 27, p. 400; *Science*, April 13, p. 176.

Electrical Traction. *Lond. Elec. Engr.*, April 20, p. 375.

Electric Tramway. (Note.) *Indust.; Lond. Elec. Engr.*, April 6, p. 315 (Vienna.)

The Observatory Hill Passenger Railway and its Electrical Apparatus. (Ill.) *N. Y. Elec. Rev.*, April, 14, p. 3. (Bentley-Knight system)

Electric Haulage in Cotton Mills. (Ill.) *Elec. World*, April 21, p. 201. *Prac. Elec.*, April, p. 210; *N. Y. Elec. Rev.*, April 21, p. 2.
Mill at Lowell, Mass., equipped with a road through the long factory building, with overhead conductor; Thomson motors.

Electrical Locomotion. (Corr.) Radcliffe Ward. *Lond. Elec. Rev.*, April 6, p. 383 *Eng.*, April 6, p. 337.

Electric Tramway in Vienna. (Note.) *Indust.; Lond. Elec. Rev.*, April 6, p. 369.

An Electro-Motor for Tramcars. (Ill.) (Corr.) C. E. *Lond. Elec. Rev.*, April 13, p. 406. A. J. Jarman. April 20, p. 431.

Electric and Magnetic Traction. (Ill.) *St. Ry. Gas.*, April, p. 46.

Ludlow's Electric Railway. *St. Ry. Gas.*, April, p. 55

Electric vs. Cable Railway. *St. Ry. Gas*, April, p 58.

Electrical Traction. *Science; N. Y. Elec. Engr*, April, p. 181.

Rapid Electric Transit. (Ill.) *Md. Lt. & Ht.*, April 5, p. 383.
(An elevated electric railway for distribution of mail matter, etc.)

Underground Electric Tramway for Paris. (Note) *Lond. Elec. Rev.*, April 27, p. 448.

Electric Traction on the Underground Railway. *Lond. Elecn.*, April 27, p. 705.

Accumulators versus Direct Currents for Electric Traction. (Ill.) W. Lineff. *Elec. World*, April 14, p. 186. (Extract from Proc. of Civ. Engrs. See *Elec. World*, Jan. 14, 1888.)

Application of the Storage Battery to Car Propulsion. (Ill.) *N. Y. Elec. Rev.*, April 7, p. 2. (Faure's.)

Horse, Steam, or Electricity. *Sci. Am.*, April 21, p. 246.

The Electrical Transmission of Energy for the Feeding of Canals. (Ill.) *Lond. Elec. Engr.*, April 13, p. 353. (M. Edmond Henry.)

Priority of Invention in Methods of Motor Regulation. I. Frank J. Sprague. *Elec. World*, April 7, p. 176. II. April 14, p. 187.

Mr. Sprague on His Defense. (Corr.) F. J. Sprague. *Lond. Elec. Rev.*, April 6, p. 376.

BATTERIES, ELECTROLYSIS, &c.

Electro-Plating. F. A. Walker. *Prac. Elec.*, April, p. 213.

Formation of the Explosive Chloride of Nitrogen by Electrolysis. (Corr.) Wm. B. Hale. *Science*, April 27, p. 206.

Electrolysis of Iron Salts. Alex. Watt. (Continued from p. 66.) *N. Y. Elec. Engr.*, April, p. 175.

Electrolysis of Lead Salts. Alex. Watt. *Lond. Elec. Rev.*, April 6, p. 356; April 13, p. 392; April 27, p. 36.

Watt's Electrotypic Zinc Process. *Lond. Mech. World; Prac. Elec.*, April, p. 212.

The Schanschieff Primary Battery. *Science*, April 6, p. 168; *Prac. Elec.*, April, p. 211.

The "Soap" Battery. (Note.) *Lond. Elec. Engr.*, April 27, p. 385. (Meserole.)

A New Dry Battery. (Ill.) *Elec. World*, April 28, p. 216. (Dr. Carl Gassner.)

A New Carbon Battery. (Ill.) *Elec. World*, April 21, p. 200. (G. E. Terrell, Inv.)

Porous Electrodes. (Note.) *Lond. Elec. Engr.*, April 13, p. 339. (Bandsept.)

Conductivity of Nitric Acid. *Elec. World*, April 28, p. 214. (M. Bouty.)

Magnesium as a Positive Element. M. Hein. *Elek. Zeits; Elec. World*, April 7, p. 175.

Magnesium in Primary Batteries. *Science*, April 13, p. 177.

Thermal Variation in Daniell Cells and Accumulators. *Wiedemann's Annalen; Lond. Elecn.*, April 20, p. 652.

Electrical Energy from Carbon Without Heat. Willard E. Case, Am. Inst. Elec. Engrs. *Science*, April 20, p. 188; *Prac. Elec.*, April, p. 212.

The Buckling of Accumulator Plates. P. Atkinson. *West. Elecn.*, April 21, p. 199.

Advice as to prevention of buckling and the treatment of buckled plates.

Secondary Battery Plates. *West. Elecn.*, April 14, p. 187. (Dujardin's method.)

New Accumulator and Electrolier Switches. (Ill.) *Lond. Elecn.*, April 27, p. 711. (Woodhouse & Rawson.)

The De Benardos Accumulator. *Science*, April 20, p. 189.

Farbacky and Scheneck Accumulators. *Science*, April 6, p. 168.

Gibson Storage Battery. *West. Elecn.*, April 21, p. 194; *Science*, April 13, p. 177.

Copper Pipes Made by Electrolysis. *Lond. Elec. Engr.; N. Y. Elec. Rev.*, April 21, p. 6.

INSTRUMENTS, MEASUREMENTS, &c.

A Simple Test for Determining the Resistance of an Earth. (Ill.) F. H. Pomeroy. *Lond. Elec. Rev.*, April 20, p. 412.

A Method of Testing Earth Resistances. (Ill. Corr.) Geo. E. Fletcher. *Lond. Elec. Rev.*, April 27, p. 464.

Construction of Resistances. (Note.) *N. Y. Elec. Rev*, April 7, p 5.

Construction of Resistance Coil Boxes. (Ill. Corr) Wm. A. Anthony *Lond. Elecn.*, April 13, p. 644.

Practical Electrical Units. W. B. Esson. (Continued from p. 222.) *Lond. Elec. Engr.*, April 6, p. 320.

The Volt, the Ohm, and the Ampere. (Ill.) Francis E. Nipher. *Elec. World*, April 7, p. 178; *Lond. Elec. Rev.*, April 27, p. 439.

A New Pattern of Reflecting Galvanometer with Lamp and Scale. (Ill.) G. L. Addenbrooke, Phys. Soc. *West Elecn.*, April 7. p. 169; *Elec. World*, April 14, p. 189.

The Ballistic Galvanometer. W. Moon. *Lond. Elec. Rev.*, April 13, p. 388.

A Proportional Reading Galvanometer. (Ill.) Dr. A. D'Arsonval. *La Lum. Elec.; Lond. Elecn.*, April 13, p. 628.

Voltmeter of the Slattery Induction System. (Ill.) *West. Elecn.*, April 28, p. 205.

Thomson's Electric Meter. (Ill.) *Elec. World*, April 28, p. 214.

A meter invented by Prof. Elihu Thomson, in which the expansion of the liquid, such as alcohol, in two bulbs, by the heating of coils in them, causes the bulbs to oscillate, and thus to register.

Improved Current Meter. (Ill.) *Sci. Am. Supp.*, April 28, p. 10,270.

A New Current Meter. R. Boernstein. *Lond. Elecn.*, April 13, p. 621.

It consists of a dynamometer whose indications are proportional to the current intensity; and of a planimeter which integrates the deflections of the dynamometer.

The Gans Wattmeter. (Ill. Corr.) Otto T. Blathy. *Lond. Elecn.*, April 6, p. 612; J. A. Fleming, April 20, p. 670.

A New Absorption Dynamometer. *Eng.*, April 20, p. 396.

A New Magnetometer. Thomas Gray, Phys. Soc. Glas. Univ. *Elec. World*, April 7, p. 175.

A Study of Certain Errors in the Constant Shunt Method. W L. Puffer, Am. Acad. Arts and Sciences. *N. Y. Elec. Rev.*, April 21, p. 2.

UNDERGROUND WIRES.

Underground Conduits in Boston. (Ed.) *Md Lt. & Ht.*, April 19, p. 437.

Underground Matters in Boston. *Md. Lt. & Ht.*, April 12, p. 420; April 19, p 437; April 26, p. 463; *N. Y. Elec. Rev.*, April 21, p. 7; April 28, p. 6.

Underground Conductors for Electric Currents. J. M. Smith, Nat Elec. Lt. Assn. *Lond. Elec. Engr.*, April 6, p. 327.

The Undergrounding of Electric Arc Light Wires. Wells W. Leggett, Nat. Elec. Lt. Assn. *Lond. Elec. Rev.*, April 6, p. 363; *Lond. Elec. Engr.*, April 6, p. 332. (Concluded from p. 305.)

THERMO-ELECTRICITY.

On Some Early Forms of Electric Furnaces. Edwin J. Houston. *Lond. Elec. Rev.*, April 6, p. 365 (Depretz's and Lontin's electric furnaces.) *Jour. Fkln. Inst.*, April, p. 300.

On Some Early Forms of Electric Furnaces. Edwin J. Houston. *Jour. Fkln. Inst.; Lond. Elec Rev.*, April 27, p. 440. (Johnson's Electric Furnace. Watson & Prosser's.)

A New Thermo-Electric Battery. (Ill.) *Lond. Elec. Rev.; Elec. World*, April 21, p. 198. (Dr. Raub.)
Comprises elements in annular shape, with a special "refrigerating" device for the forcible introduction of air.

E. Raub's New Thermo Battery. (Ill.) G. Betz. *Lond. Elec. Engr.*, April 13, p. 350; *N. Y. Elec Rev*, April 21, p. 1.
Abs. of paper in *Cent. für Elek.*

A New Thermo-Electric Element. M. Heimel. *L'Electricien; Elec. World*, April 7, p. 174.

MISCELLANEOUS.

Curious Facts Relative to Alloys. *Pop. Sci. News; Sci. Am.*, April 14, p. 232.

Alloys. W. C. Roberts-Austen, Soc. Arts, Lond. *Sci. Am.*, April 28, p. 265.

Magnesium. *Lond. Elecn.*, April 27, p. 686.

Fluorine a Universal Solvent. *Iron; Sci. Am.*, April 21, p. 242.

Isolation of Fluorine. A. E. Tutton. *Nature; Jour. Fkln. Inst.*, April p. 314.

Peculiar Properties of Selenium. *Elec. World*, April 7, p. 175.

The Electric Resistance of Cobalt. Dr. G. Faé. *Eng.; Elec. World*, April 7, p. 179.

The Conductivity of Boiling Sulphur. *Comptes Rendus. Elec. World*, April 28, p. 214. (M. Duter.)

Elements and Meta-Elements. Wm. Crookes, Chem. Soc. *Lond. Elec. Engr.*, April 6, p. 328.

Hydrogen Peroxide. (Note.) *Lond. Elec. Engr.*, April 13, p. 340.

Electrical Resistance of Nickel. (Note.) *Lond. Elec. Engr.*, April 27, p. 385. (A. Batelli.)

The Electrification of Soap Bubbles. *Lond. Elecn.*, April 20, p. 672. (Phys. Soc.)

Saunders' Lightning Guard. (Ill.) *Lond. Elecn.*, April 27, p. 711.

Protection of Buildings from Lightning. *West. Elecn.*, April 21, p. 199. (Oliver J. Lodge.)

The Protection of Buildings from Lightning. *N. Y. Elec. Rev.*, April 14, p. 6.

A Lightning Rod Fallacy. *Building; Md Lt. & Ht.*, April 26, p. 461.
A correction of some lightning rod fallacies, and as to the necessity of a large ground plate, well sunken in moist ground.

The Royal Meteorological Society's Exhibition. (Ill.) W. Marriott. *Lond. Elecn.*, April 6, p. 593; April 13, p. 631.

Hail and Electricity. *Md. Lt. & Ht.*, April 19, p. 443. (M. Dary in *L'Electricité.*)

Meteorology. *Sci Am Supp.*, April 28, p. 10,265.
Electrical and meteorological observations on the Summit of Teneriffe.

Electric Leakage in Moist Air. *Beiblätter; N. Y. Elec. Rev.*, April 28, p. 1.

Electricity and Tornadoes. H. Allen Hazen. *St. Louis Globe-Dem.; N. Y. Elec. Rev.*, April 21, p. 9.

Action of Atmospheric Electricity on Rain. *Elec. World*, April 7, p. 175.
Soc. of Arts, "Protection from Lightning." Prof. Oliver J. Lodge.

A New Frictional Machine. (Note.) *Lond. Elec. Rev.*, April 27, p. 448. (Tudsbury.)

An Application of Static Electricity. Use of the Static Spark for Instantaneous Illumination. *Sci. Am. Supp.*, April 7, p. 10,230.

Atmospheric Electricity. *Sci. Am.*, April 28, p. 261. (Dr. Marcet, Roy. Met. Soc.)

Protection of Wires. (Note.) *Lond. Elec. Engr.*, April 13, p. 338.

A New Process for Insulating Wires. *Centralblatt. für Elek.; Elec. World*, April 21, p. 204. (Weber and Schefbauer.) *Prac. Elec.*, April, p. 212.

Gilbert's Arm-Setter. (Ill.) *Lond. Elec. Rev.*, April 6, p. 360. (Gilbert.)
An instrument to secure the setting of pole arms at exact right angles.

Aerial Wires. *Eng.*, April 6, p. 344.

Letters for Learners and Unprofessional Readers. (Ill.) H. D. Wilkinson. *Lond. Elecn.*, April 6, p. 595; April 27, p. 689.

Difference of Potential and Electric Current. "Zeta." *West. Elecn.*, April 7, p. 172.

Advantages of Electricity for Railroad-Work. *Science*, April 27, p. 200.

The Radiograph. L. Olivier. *Comptes Rendus. Lond. Elecn.*, April 13, p. 637.

An Improved Electrical Speed Indicator. (Ill.) *Sci. Am.*, April 28, p. 259. (Fred. W. Schlepegrell.)

Electricity in the Service of Man. *Md. Lt. & Ht.*, April 5, p. 380. (An elec. entertainment, Newton Centre, Mass., lecture by Mr. A. L. Rohrer.)

Large Switchboards. (Note.) *Lond. Elec. Rev.*, April 27, p. 448. (Ill.) *Lond. Elecn.*, April 20, p. 654.

Safeguard Against Shock from High Tension Currents. (Ill.) P. B. Delany. *Elec. World*, April 7, p. 179. Protection of Linemen Against Shock. (Corr.) April 21, p. 200.

Metallic bracelets and leglets for shunting a part of the current.

Maturing Wines by Electricity. *Elec. World*, April 21, p. 201.

Prices in America. (Note.) *Lond. Elec. Engr.*, April 13, p. 339.

Australia. (Note.) *Sydney Morning Herald; Lond. Elec. Engr.*, April 13, p. 340.

Sir Humphey Davy. (With Portrait.) *Lond. Elec. Engr.*, April 20, p. 371.

Electrical Images. *West. Elecn.*, April 14, p. 183.

Image obtained, for example, when a piece of glass separates a sheet of tin foil and a coin, and the metals are connected to a frictional machine.

The Holroyd Smith Magnetic Separator. (Ill.) *Indust.*, April 13, p. 381.

Electric Rifles. *Eng.*, April 13, p. 369.

Electricity in Medicine. *Medical Press; Lond. Elecn.*, April 27, p. 684.

Electricity and Surgery. (Note.) *Lond. Elec. Rev.*, April 6, p. 371.

Magnetization in Steel Bars. *Lond. Elec. Rev.; West. Elecn.*, April 7, p. 177.

Practical Uses of the Electro-Magnet. *Pittsburgh Press; Sci. Am.*, April 28, p. 260.

An Electro-Magnet that can Pick Up 800 Pounds of Iron and Carry it About. *Pittsburgh Press; N. Y. Elec. Rev.*, April 28, p. 3.

Tubular Magnets. M. Ernest Gérard. *Bul. de la Soc. Belge d'Elect.; Elec. World*, April 7, p. 175.

Some Experiments with an Electro-Magnet. Geo. M. Hopkins. (Ill.) *Sci. Am.*, April 7, p. 214.

The Copper Syndicate. *Lond. Statist; N. Y. Elec. Rev.*, April 14, p. 6.

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LORD BACON.